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Early Warning and Crop Condition Assessment

A Joint Program for Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing

May 1983

SIMULATION OF METEOROLOGICAL SATELLITE (METSAT) DATA USING LANDSAT DATA

W. W. Austin and W. E. Ryland

Lockheed Engineering and Management Services Company, Inc.

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16. Abstract

This report documents the results of a task designed to assess the information content which can be expected from the advanced very high resolution radiometer system, AVHRR, on the National Oceanic and Atmospheric Administration satellite, NOAA-6, and to define systematic techniques of data interpretation for use with meteorological satellite data. To accomplish these objectives, existing Landsat data were used to simulate the meteorological satellite data.

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PREFACE

The Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing is a multiyear program of research, development, evaluation, and application of aerospace remote sensing for agricultural resources, which began in fiscal year 1980. This program is a cooperative effort of the U.S. Department of Agriculture, the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration (U.S. Department of Commerce), the Agency for International Development (U.S. Department of State), and the U.S. Department of the Interior.

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1. INTRODUCTION

Data from meteorological satellites (metsats) have been used satisfactorily to supplement data from the land satellite (Landsat) system. This report documents the results of a task designed (1) to assess the information content which can be expected from use of metsat data, specifically from the advanced very high resolution radiometer (AVHRR) on the National Oceanic and Atmospheric Administration (NOAA) satellite NOAA-6, and (2) to define systematic techniques of data interpretation for use with metsat data. To accomplish the objectives of this task, existing Landsat data were used to simulate the metsat data.

The technical approach for the task and the technique used to simulate the metsat data are described in section 2; a description of the procedures followed in this task and the results of applying these procedures to one Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing (AgRISTARS) site are also given in section 2. Simulated coverage over different geographical areas is compared in section 3. Simulated coverage of different year data over the same geographical areas is compared in section 4. Results are summarized and recommendations are presented in section 5. A description of the meteorological satellite data simulation software program, METSIM, developed for use in this task is included as appendix A.

2. TECHNICAL APPROACH

2.1 OVERVIEW

The task was divided into three phases. After completion of each phase, the task direction was reassessed; each phase depended upon the results of the previous phase.

Phase 1 was an exploratory phase for task definition; appropriate software was developed, and a tentative analysis procedure was defined. A 1978 crop-year site, sample segment 886 in Pottawattamie County, Iowa, was used to develop software and to define an analysis technique.

Phase 2 was a geographical expansion of phase 1. Eleven additional sample segments were graphed using the software program developed in phase 1, and the results were analyzed.

Phase 3 expanded the application of the software and the analysis procedure to multiyear coverage over the same geographical area. Two spring wheat sites and two corn/soybean sites were used in this phase. Data were taken from crop years 1977, 1978, and 1979. At the time of this study, 1980 crop-year Landsat coverage was not available.

2.2 DATA SET

All segments selected for use in this task had the accuracy assessment (AA) digitized ground truth available. Segments were selected from reference 1 with additional multiyear sites from reference 2.

2.3 SOFTWARE REQUIREMENTS

Completion of this task depended on development of the software program METSIM. METSIM provids the capability of simulating data from the AVHRR system on NOAA-6, using existing Landsat data. With this program, research can proceed by using Landsat data until such time as metsat data is available in an operational mode.

Requirements for the software program were:

- Simulate the local area coverage (LAC).
- Simulate the metsat global area coverage (GAC).
- Generate a multitemporal profile of segment content.
- Utilize ground truth information (1) to generate profiles of single scene components such as corn or (2) to filter out nonvegetative components from inclusion in the averages.
- Utilize the picture element (pixel) purity information available in the AA digitized ground truth maps.
- Provide statistical as well as graphic information.
- Provide the capability of fitting a curve to the data so that profiles could be compared.
- Provide the capability of adjusting the data range for Landsat-3 acquisitions into that for Landsat-2 acquisitions.

A step-by-step guide to use of METSIM is given in appendix A.

2.4 SIMULATION TECHNIQUES

2.4.1 SPECTRAL SIMULATION

The NOAA-6/AVHRR receives data in four bandwidths, two reflective and two predominately emissive. Landsat multispectral scanner (MSS) channels 2 and 4 are roughly comparable to AVHRR reflective bands 1 and 2. The channel bandwidths are: for MSS channel 2, 0.6 to 0.7 micrometer; for AVHRR channel 1, 0.55 to 0.68 micrometer; for MSS channel 4, 0.8 to 1.1 micrometers; and for AVHRR channel 2, 0.72 to 0.96 micrometer.

Two characteristics of the NOAA-6/AVHRR system increase the possibility of the atmosphere affecting the metsat data more than it affects the Landsat data: (1) the total scan angle is much larger, and (2) the zenith angle of the Sun is larger. The scan angle of NOAA-6 is 110° and that of Landsat is 7°. NOAA-6 pass time is approximately 7:30 a.m., and the pass time for Landsat is

9:30 a.m. The use of channel ratio decreases the atmospheric effect on data and lessens this difference between the systems. For this task, the ratio of the value in MSS channel 4 over the value in MSS channel 2, multiplied by 20, was graphed against time (acquisition date).

2.4.2 SPATIAL SIMULATION

The NOAA-6 satellite scans a 110° angle from 525 miles, or 844 kilometers, above the Earth. This scan angle subtends 2048 pixels; at nadir, the metsat pixels are 1.1 kilometers square. Pixel size increases with distance from nadir, because pixels are subtended by equal angles (ref. 11).

For this task, a metsat pixel was simulated by a grouping of 13 (lines) by 17 (columns) Landsat pixels. An AgRISTARS sample segment of Landsat data is 5 by 6 nautical miles, or 9 by 11 kilometers, in area. Consequently, to cover a 1.1-kilometer square (the area of a metsat pixel) required 221 Landsat pixels. This cell of Landsat pixels simulated the basic element of NOAA-6 full-resolution coverage.

2.4.3 SIMULATION OF METSAT COVERAGE

The AVHRR receives six scans of data per second; a scan is 2048 pixels. The onboard Manipulated Information Rate Processor (MIRP) transmits by direct broadcasting and also records on board for delayed broadcast (fig. 2.4-1). Full-resolution data, LAC, or sampled data, GAC, can be obtained.

Full-resolution LAC provides a data value for every metsat pixel. These data are broadcast continuously for line-of-sight from the satellite by high-resolution picture transmission (HRPT). For the United States, data are received at Wallops Island, Virginia, recorded, and archived. Full-resolution coverage over areas not a line-of-sight from Virginia can be recorded on board for delayed transmission. Consequently, LAC of areas such as South America can be obtained by prior request so that the onboard recorder can be activated by ground command.

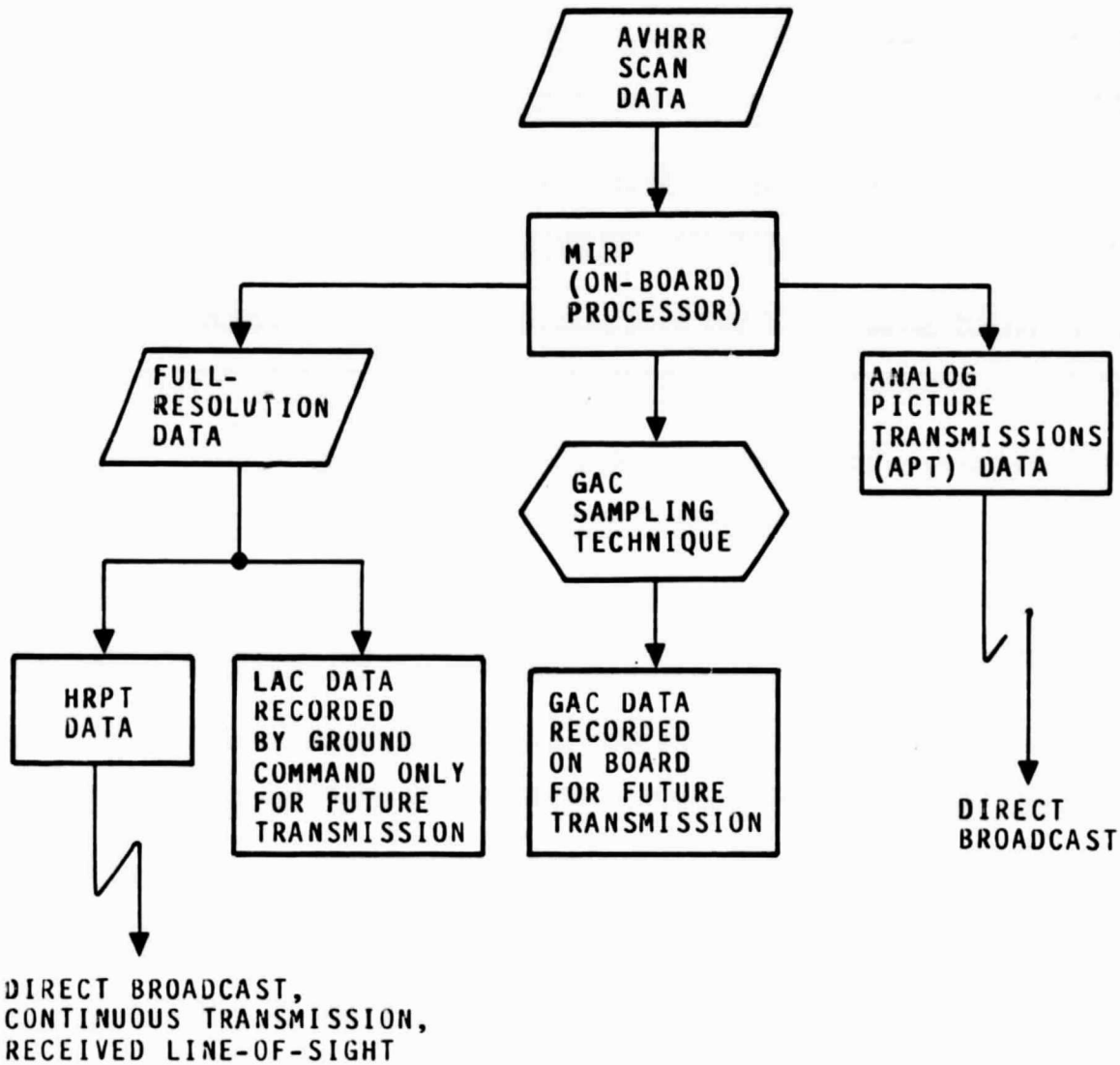

Figure 2.4-1. -Transmission of metsat data.

GAC data are sampled from the full-resolution AVHRR data. GAC sampling provides a data value which is the average of four contiguous pixels. On every third scan, four pixels are averaged for a data value, the fifth pixel is skipped, and then four more pixels are averaged. This is repeated for the scan. Consequently, on a sampled scan line, 409 data points are recorded for the 2048 pixels. The sampling technique for six lines is:

```
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
X X X X 0 X X X X 0 X X X X 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
X X X X 0 X X X X 0 X X X X 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

with the mean value of the four sampled pixels recorded. Each group of four full-resolution points (X) represents one GAC value.

For this task, LAC was simulated by a cell: 221 Landsat pixels grouped 13 lines by 17 columns on the sample segment. GAC was simulated by a block: a grouping of 16 cells, 4 cells by 4 cells, or 68 Landsat columns by 52 Landsat lines. The software program provided flexibility in positioning the blocks; hence, the entire sample segment could be included in the simulation. Block location determined the location of the cells; cell location was a grid that was fixed relative to the block. Cell locations referenced to the lines and pixels in the sample segment were provided automatically on the graphs generated by the software program.

2.5 PROCEDURE

Use of the software program METSIM was central to the completion of this task. The overall procedure was divided into three steps: (1) the preprocessing necessary to create the merged image files input to METSIM, (2) the generation of graphs using METSIM, and (3) the analysis of the graphs.

2.5.1 PREPROCESSING

Figure 2.5-1 illustrates the data flow through the software programs used in this task. These are the steps:

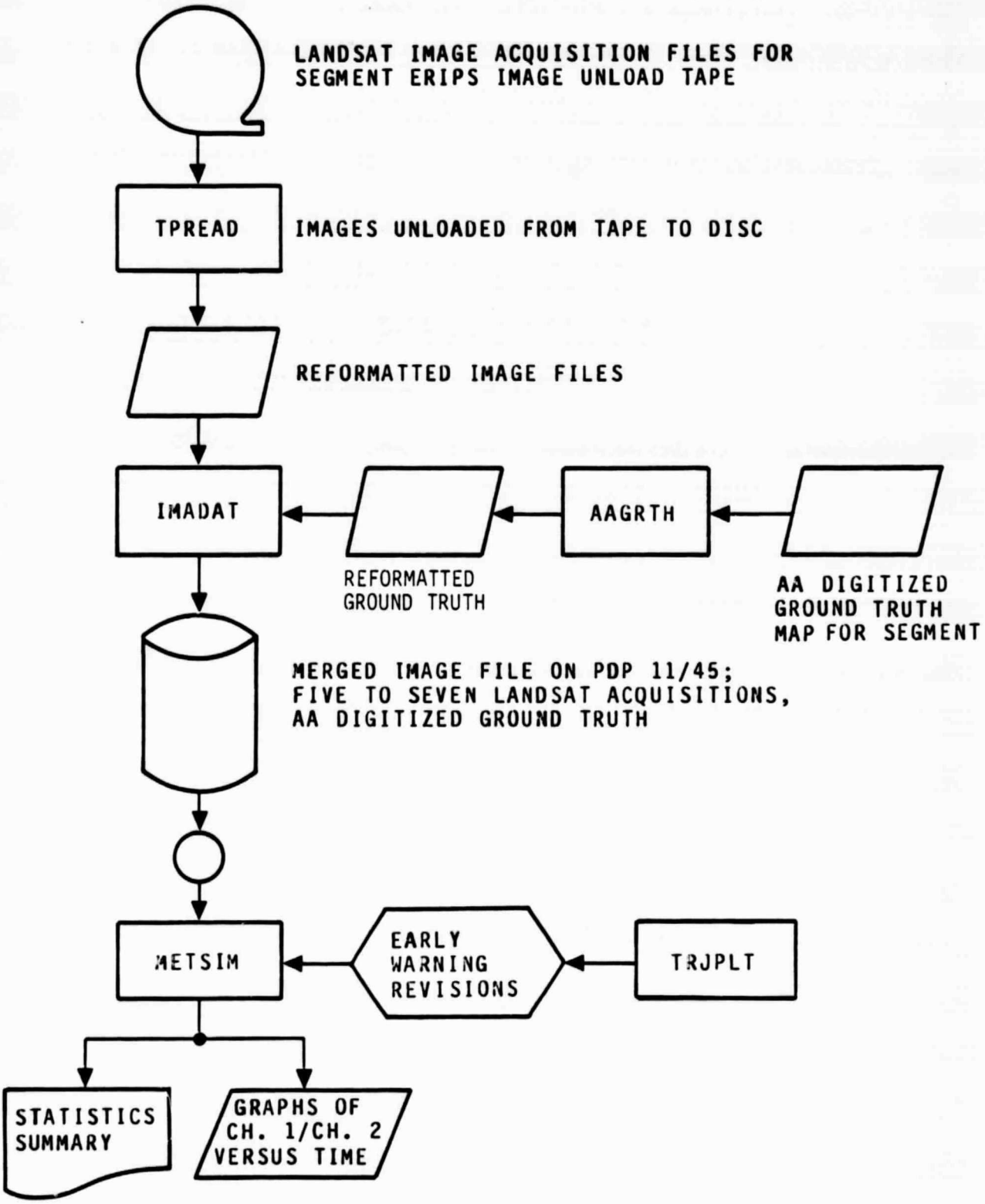

Figure 2.5-1.—Software flow chart.

1. Site selection was made from the AgRISTARS sites with 1978 crop-year acquisitions (ref. 1).

2. Production film converter (PFC) products were screened for data quality of each acquisiton for the segment. Acquisitions were rejected if the cloud cover was more than 30 percent of the scene or if haze was evident. From four to seven acquisitions were selected for each site during the vegetation growing season.

3. Image unload tapes generated on the Earth Resources Interactive Processing System (ERIPS) were acquired for the sites and acquisitions selected.

4. Images were unloaded from the tapes by using the software program TPREAD. (Software programs TPREAD, AAGRTH, and IMADAT were written by G. D. Badhwar, and he made these programs available for Early Warning use.) The TPREAD program was used to reformat data from an image unload tape generated on the ERIPS system, and to load the reformatted image onto a PDP 11/45 disc.

5. The AA digitized ground truth maps were reformatted using the software program AAGRTH.

6. Selected acquisitions were merged with the ground truth files by using the software program IMADAT. IMADAT merged 4, 5, 6, or 7 Landsat acquisitions that were reformatted by using TPREAD with the digitized ground truth maps that were reformatted by using AAGRTH. Output was the merged image file used as input to METSIM.

2.5.2 PROCESSING

The input to METSIM is a file that consists of four to seven acquisition images plus the AA digitized ground truth pixel identification. Output is: (1) a graph which is the ratio of MSS channel 4 spectral value to channel 2 spectral value versus time; and (2) a hardcopy of cell mean values for each acquisition and the number of pixels providing input to the mean value computations.

Graphs can be generated for the mean value of a single cell or the mean values of each of the 16 cells in a block; graphs can also be generated for the block

mean values. The mean values of the cell can be computed several ways: (1) use pixels of a specific crop only as input; (2) use all 221 component Landsat pixels as input; (3) use a preset filter to omit all noncrop pixel input; or (4) specify a filter of the AA crop code identifications to be omitted as input. The AA pixel purity codes of "1" to "6" can also be applied to the input to the mean value. This provides sensitivity for comparison of the information content which can be expected from metsat data.

Procedures evolved that were based on an analysis of previous results in this task. Generation of graphs for sample segment 886 (used in development) was considerably more extensive than for subsequent processing. For each segment, however, the following graphs were produced:

a. Major crops of the segment using the crop code option, pixel purity 6, derived from a block.

b. Simulated GAC-scale coverage (blocks), all pixels (purity 1); nine block positions to completely cover the segment. Block positions (001,001), (001,069), (053,001), and (053,069) cover most of the segment; additional block positions (001,129), (053,129), (065,001), (065,069), and (065,129), complete segment coverage. This involves overlap in all block positions except block position (001,001); eight columns and 40 lines in the segment have repeat coverage.

c. Simulated GAC-scale coverage, all pixels (purity 1) input to the mean values and vegetated pixels only (using preset filter capability) input to the mean values for the block simulation most likely to be affected (i.e., the block with the most nonvegetation content).

d. Simulated LAC-scale coverage, all pixel (purity 1) input, for each cell in one block position.

The curve fit option was selected for all graphs. If an acquisition was seriously out of line, as is acquisition 78212 for sample segment 886, curves were fitted by omitting the acquisition. Initial-guess input to aid curve convergence was adjusted for each site, but the input was generally consistent for all processing on the site. Certain crop profiles, such as a summer crop in a spring vegetation area, required special adjustment of initial guesses.

2.5.3 ANALYSIS PROCEDURE

The following analysis procedure was defined using sample segment 886 and then applied to the 11 segments processed for phase 2.

a. Background material about the segment, including observations on acquisition data quality, was compiled for reference.

b. Crop profiles for major scene components were examined.

c. Block signatures were assessed for definition of a GAC scale signature representative of the segment. The curve fit approximations were compared by recording the constant values A, α, and β, which are derived for the equation of the approximating curve. The value of t_o, the estimated planting date, was also recorded. A "segment profile", was defined when possible. For one block, the "vegetation only" input signature was compared with the "all pixel" signature. From this, the degradation of the segment/GAC signature caused by nonvegetation input was discussed.

d. Cell signatures were compared with the crop profiles and ground truth map. Degradation of profile caused by cell-level averaging was discussed.

e. Segment analysis was summarized and documented.

Multiyear comparison was done at block/GAC level only.

a. Major scene component profiles were compared.

b. Block signatures were compared for four blocks with no overlap in coverage, and compared on the same geographical area. Segment location was not perfectly registered between years, so an adjustment of block positions was required.

c. Analysis was summarized and documented.

2.6. SIMULATION OF METSAT COVERAGE OVER SAMPLE SEGMENT 886, POTTAWATOMIE COUNTY, IOWA

2.6.1 DISCUSSION

LACIE sample segment 886, Pottawatomie County, Iowa, was selected for use in the development of the METSIM program. This segment choice was adequate for

program development, but the segment was 47 percent soybeans, providing little contrast in land usage. The acquisitions merged for processing were these:

Julian date	Landsat	Comments
78167	2	Pasture, hay, grains, and trees in vigorous growth; summer crop: barely emergent
78204	2	Slight haze; all vegetation in vigorous growth
78212	3	Several popcorn clouds; grains harvested
78231	3	Three clouds, some corn senescent
78249	3	Corn senescent
78258	2	Some corn harvested; soybeans in vigorous growth
78267	3	Much of the corn is harvested

Data quality of the acquisitions was not ideal, but the acquisitions were well distributed relative to the growth cycle of summer vegetation.

The following experimentation was done on this segment:

a. Comparison was made of Landsat-3 adjusted and nonadjusted signatures of corn, soybeans, homestead, and bare soil. The satellite source sequence of acquisitions: Landsat 2, Landsat 2, Landsat 3, Landsat 3, Landsat 3, Landsat 2, Landsat 3 means that the overall shape of the signatures could be altered by applying the Landsat 3 adjustment. However, the adjustment may not make a statistically significant change in data values. Figure 2.6-1a illustrates a corn signature without the Landsat 3 adjustment and 2.6-1b illustrates this with adjustment; figures 2.6-2a and b illustrate the Landsat 3 adjustment on the soybean signature.

b. Ratioed spectral values over all the segment were markedly lower on day 78212 (July 31) than on day 78204 or 78231. This dip in the ratio signature on day 78212 was investigated. The major source of the decrease in ratio value is apparently the increase in value of the channel 2 input.

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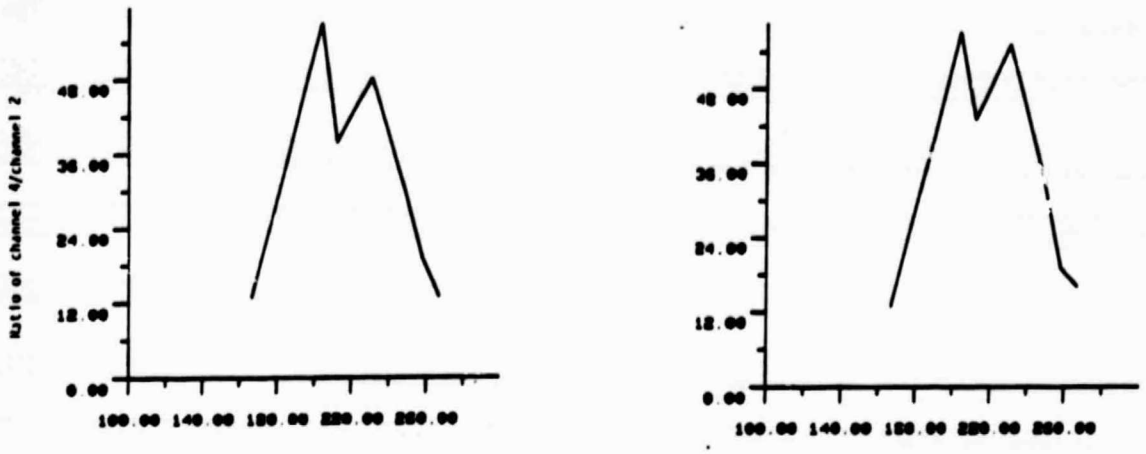
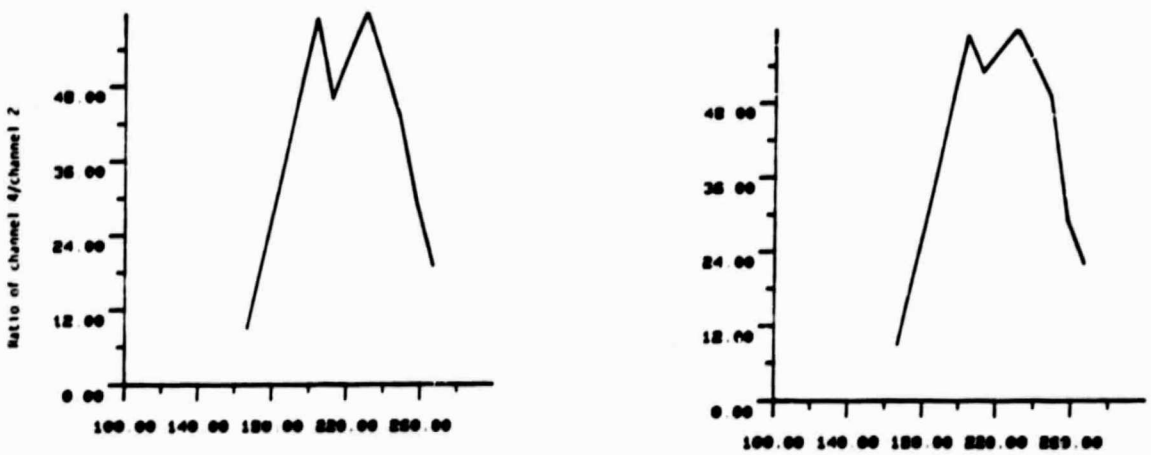


(a). Corn signature with adjustment

(b). Corn signature without adjustment

Figure 2.6-1.-Comparison of Landsat-3 adjusted and unadjusted corn signatures.



(a). Soybean signature with adjustment

(b). Soybean signature without adjustment

Figure 2.6-2.- Comparison of Landsat-3 adjusted and unadjusted soybean signatures.

The software program IMAPLT[2] was used to graph the values of individual channels which were input to the ratio. Figures 2.6-1 to 2.6-4 are graphs generated using IMAPLT for 45 pixels in cell 1, block position (001,001). Each line on the graph is a Landsat pixel in the cell area; each graph is the spectral value in an MSS channel versus time (5 acquisitions: 78167, 78204, 78212, 78231, 78249). Individual channel input was plotted for a soybean field, a cornfield, a homestead area, and an apparent bare soil area. The dip was more pronounced in the more vegetated areas on acquisition day 78212, but it existed in all areas.

Candidate causes of the data dip are presented:

- High cirrus clouds which were not evident in the PFC film products. Full-frame coverage for acquisition day 78212 confirms the presence of cirrus clouds in the area. Atmospheric effect as a cause for data dip is also supported by a recent publication on haze (ref. 6).
- Poor vegetative condition. Loss of chlorophyll absorption, evidenced by a rise in channel 2 values on this date, may have resulted from moisture stress (ref. 7) or from the dry, hot conditions of midsummer.
- Data taken from a different sensor scan angle. The acquisition on day 78212 was taken from a different spacecraft orbit than that on day 78207 or 78231 (refs. 6 and 8). Julian date acquisitions 78167 and 78212 are row-path 29-31; days 78204, 78231, 78249, 78258, and 78267 are row-path 30-31 (refs. 6 and 8). However, difference in scan angle should not affect a ratio based signature.

c. Detector response over vegetation was examined. Individual detectors within each MSS sensor may not give consistent output for equal input; this effect is more prevalent over vegetation. The program IMAPLT was used to check this on the MSS channel input. Nine pixels in the interior of a soybean field were averaged; seven lines were graphed. Since there

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[2]The software program IMAPLT is by G. D. Badhwar. It is an extremely useful research tool, because it provides a method of dividing a vegetative index, such as ratio, into its component inputs from the MSS channel; data can be related more directly to agronomic factors.

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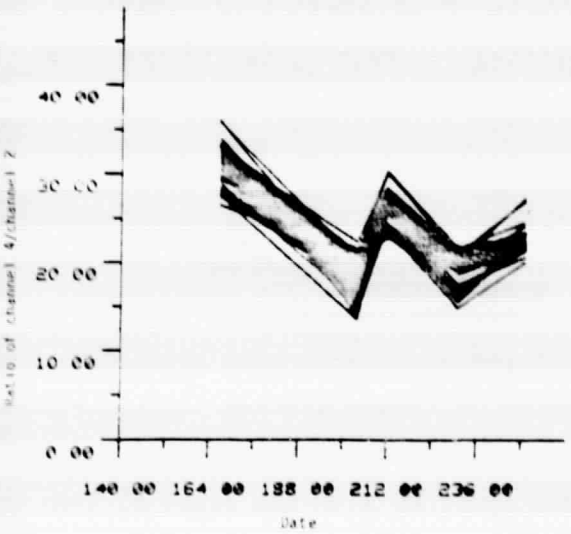

Figure 2.6-3. -Landsat pixels, reflectance versus time, MSS channel 1.

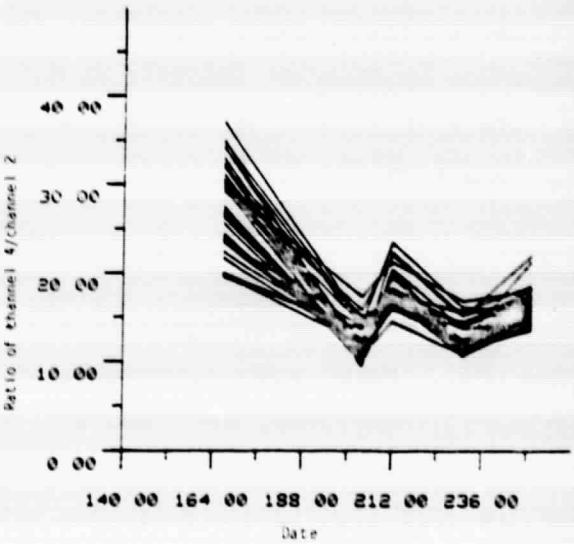

Figure 2.6-4. -Landsat pixels, reflectance versus time, MSS channel 2.

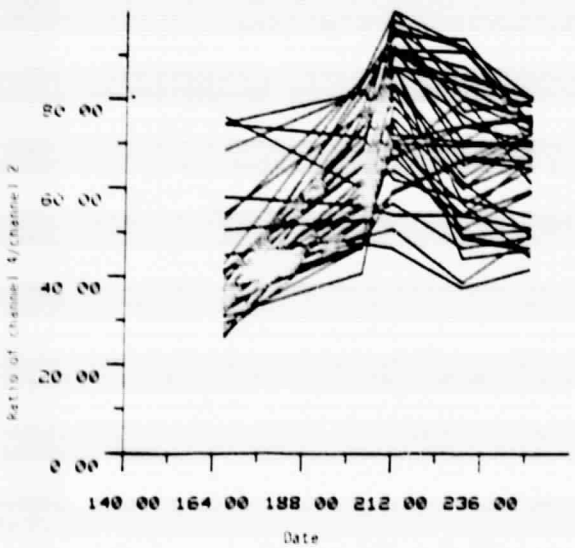

Figure 2.6-5. -Landsat pixels, reflectance versus time, MSS channel 3.

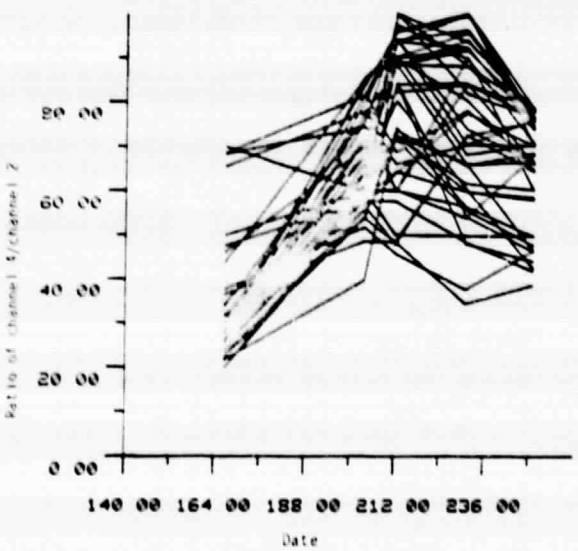

Figure 2.6-6. -Landsat pixels, reflectance versus time, MSS channel 4.

are six detectors, each the source of one scan line of data, this assures that the output of each detector is sampled. Since each acquisition may map a different pixel area, separate graphs were compiled for each acquisition line versus channel. Figures 2.6-7 (a) through (e) illustrate these channel soybean profiles for each seven-line acquisition. Differences in detector response appear insignificant. Mean values of the lines are plotted on figure 2.6-8, acquisition day versus the ratio of channel 4 to channel 2.

2.6.2 MAJOR SCENE COMPONENTS

Figure 2.6-9 is the AA digitized ground truth map covering block position (001,001). Major scene components of corn, soybeans, summer crop (corn and soybeans), homestead, and trees are illustrated in figure 2.6-10.

For the crop signatures, data mean values are compared with the value of the curve fitted to the data in the chart below. The fitted values are for a curve fitted through six acquisitions, omitting day 78212; Landsat-3 acquisitions were calibrated by the Wehmanen adjustment (ref. 5). Signatures were obtained from pixels of crop purity 6 in the block positioned at (001,001). The constant values A, α, and β derived for the equation

$$P_V(t) = At^{\alpha}e^{(-\beta t^{Z},)}$$ where $P_v(t)$ is the reflectance at time t

of the curve are given, as are the chi-square fit of the curves to the data. The estimated vegetation emergence data, t_o, is also listed.

Crop	78167	78204	78212	78231	78249	78258	78267
1. Corn:							
Mean values of data	11.1	54.5	32.5	45.9	29.9	18.3	14.0
Value of fitted curve	11.9	52.4	-	48.5	28.7	19.3	11.0
A = 1.8, α = 28.6, β = 3.1, t_o = 1.58, chi-squared fit = 1.9							
2. Soybeans:							
Mean values of data	9.9	56.3	40.6	70.0	42.9	24.7	18.5
Value of fitted curve	9.6	61.7	-	67.6	42.9	29.5	18.6
A = 1.6, α = 31.9, β = 3.3, t_o = 160, chi-squared fit = 0.6							

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Line	Ch. 1	Ch. 2	Ch. 3	Ch. 4
3	32.1	30.0	35.7	27.9
4	30.7	29.1	35.1	26.4
5	30.6	28.4	33.4	26.4
6	31.7	28.9	33.0	27.0
7	32.1	29.0	34.9	27.5
8	32.1	30.8	37.4	28.8
9	32.4	30.6	35.6	29.3

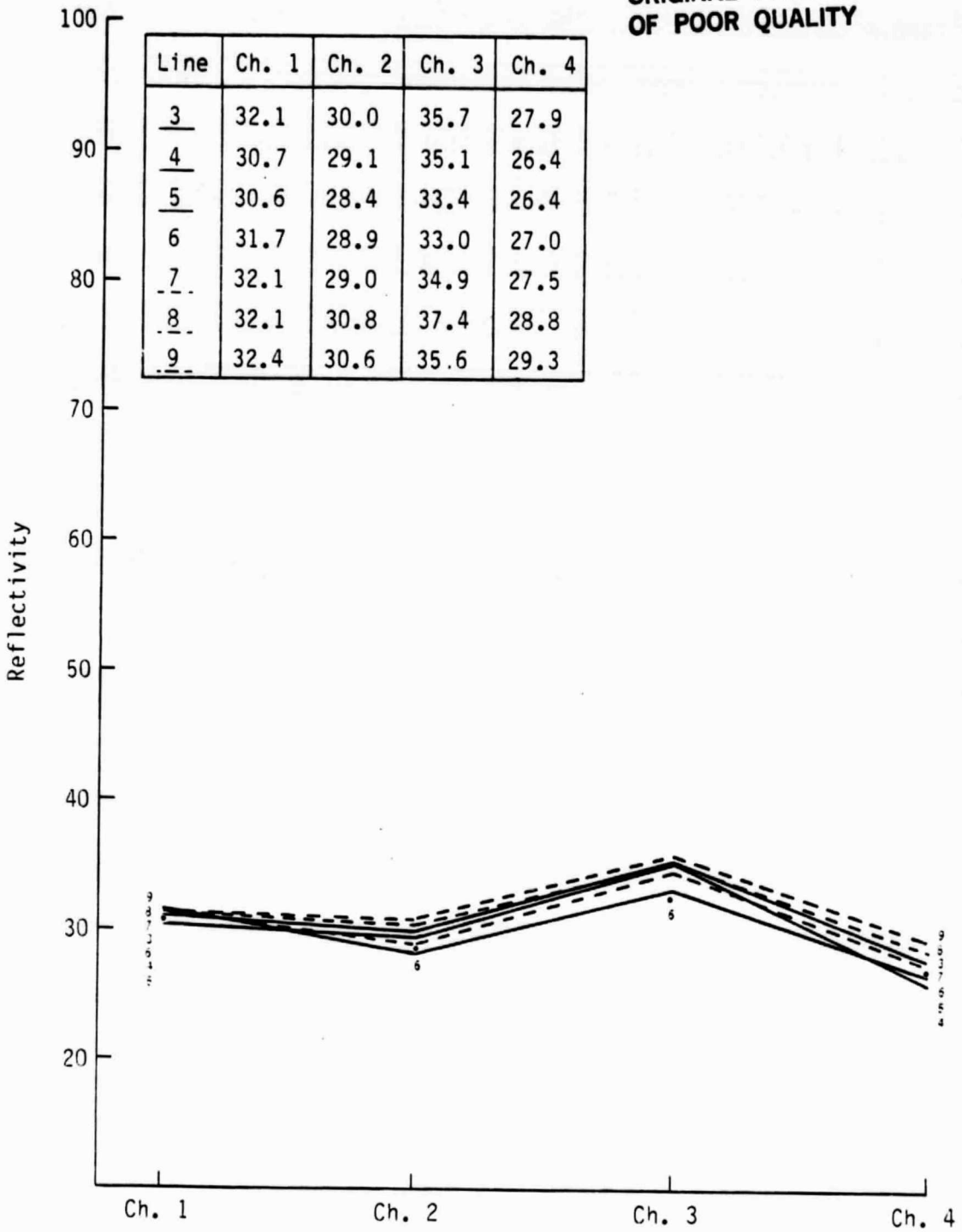

Figure 2.6-7a.–Mean values of nine-pixel lines for soybean field for acquisition day 78167 (Landsat 2).

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Line	Ch. 1	Ch. 2	Ch. 3	Ch. 4
3	19.3	11.9	70.8	71.6
4	18.9	11.9	74.2	71.8
5	19.6	12.4	72.3	76.7
6	17.7	12.2	74.0	71.2
7	18.7	12.3	73.2	72.9
8	19.8	13.4	71.9	74.0
9	22.3	15.2	84.7	85.6

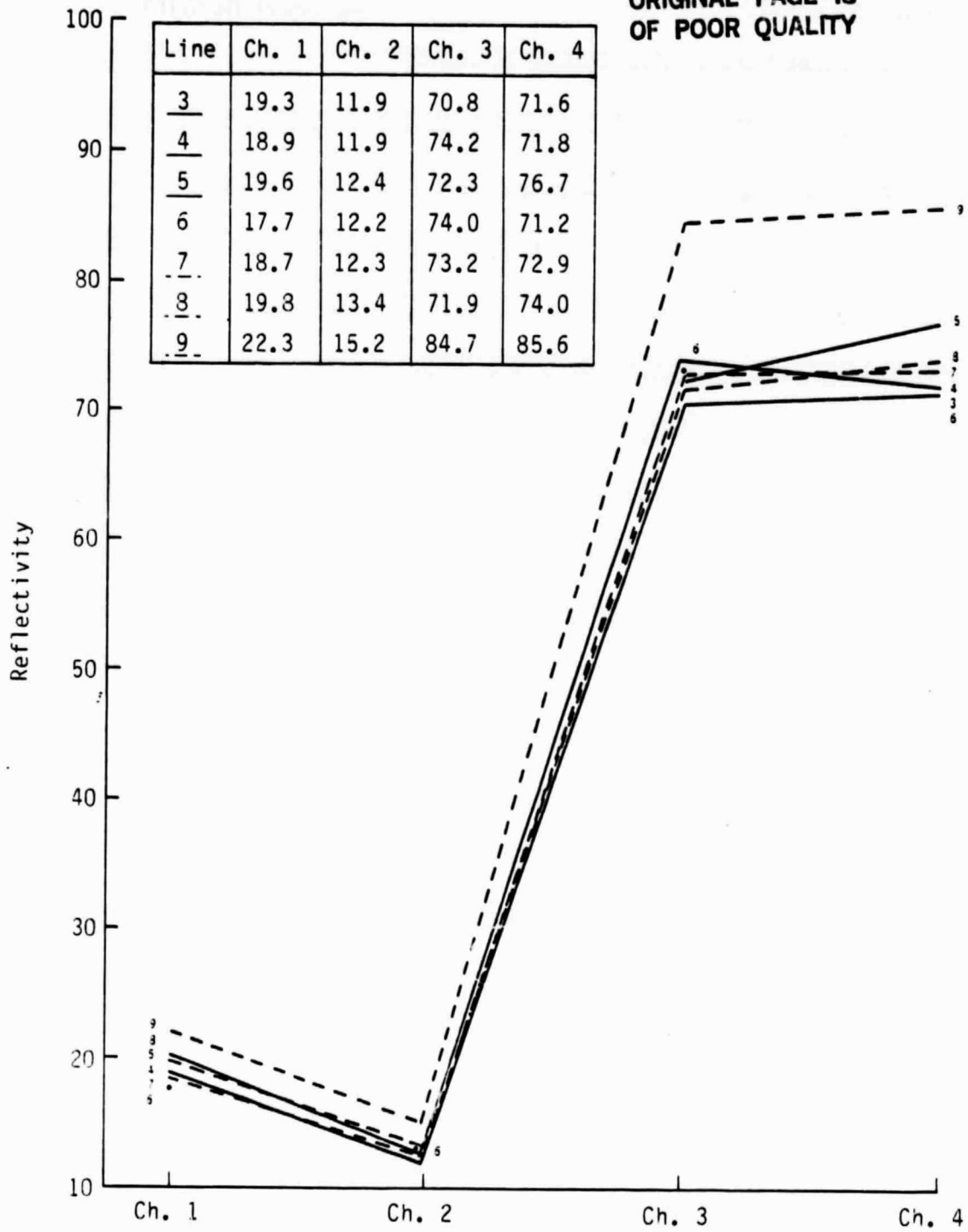

Figure 2.6-7b.-Mean values of nine-pixel lines for soybean field on acquisition day 78204 (Landsat 2).

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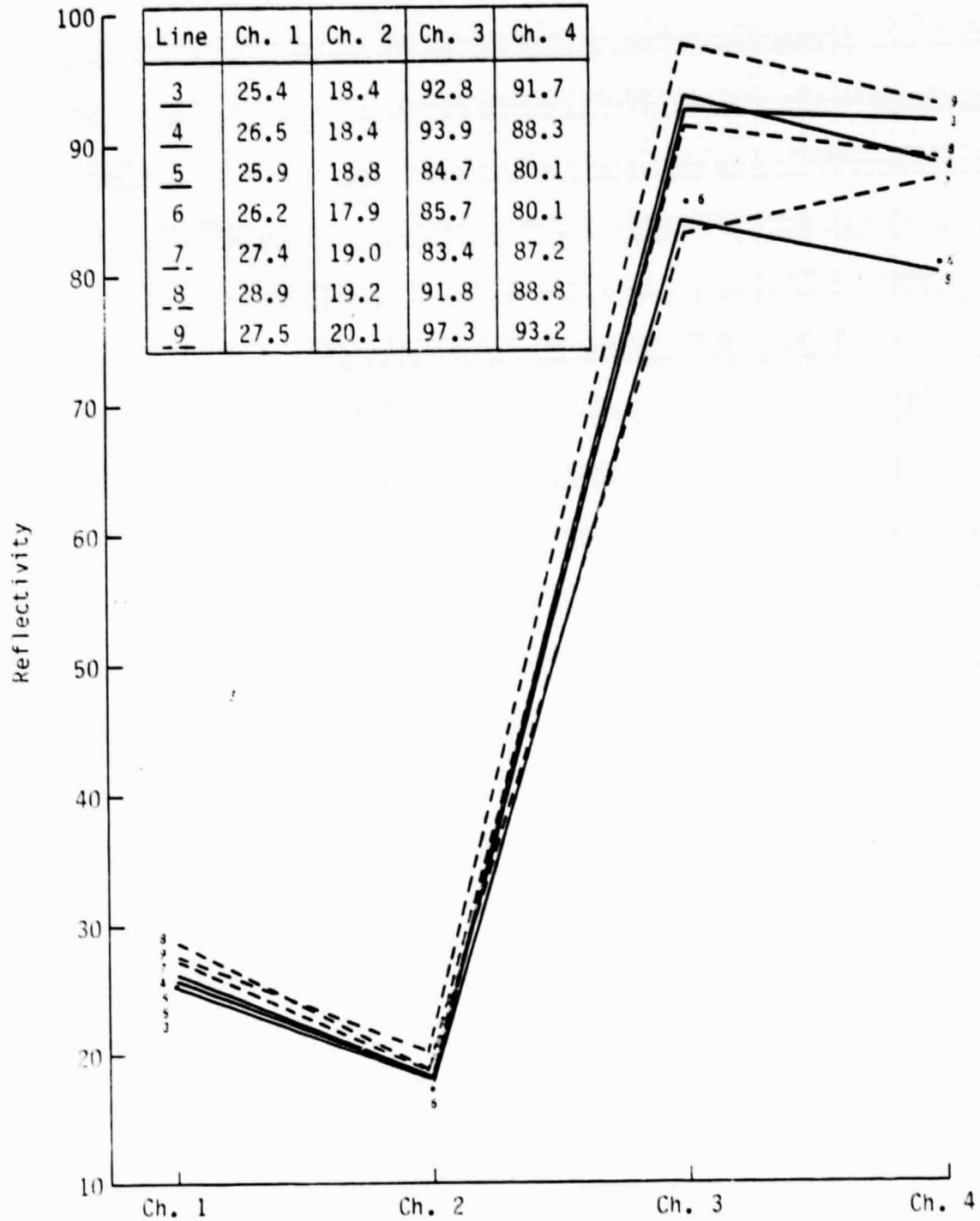

Line	Ch. 1	Ch. 2	Ch. 3	Ch. 4
3	25.4	18.4	92.8	91.7
4	26.5	18.4	93.9	88.3
5	25.9	18.8	84.7	80.1
6	26.2	17.9	85.7	80.1
7	27.4	19.0	83.4	87.2
8	28.9	19.2	91.8	88.8
9	27.5	20.1	97.3	93.2

Figure 2.6-7c.—Mean values of nine-pixel lines for soybean field for acquisition day 212 (Landsat 3).

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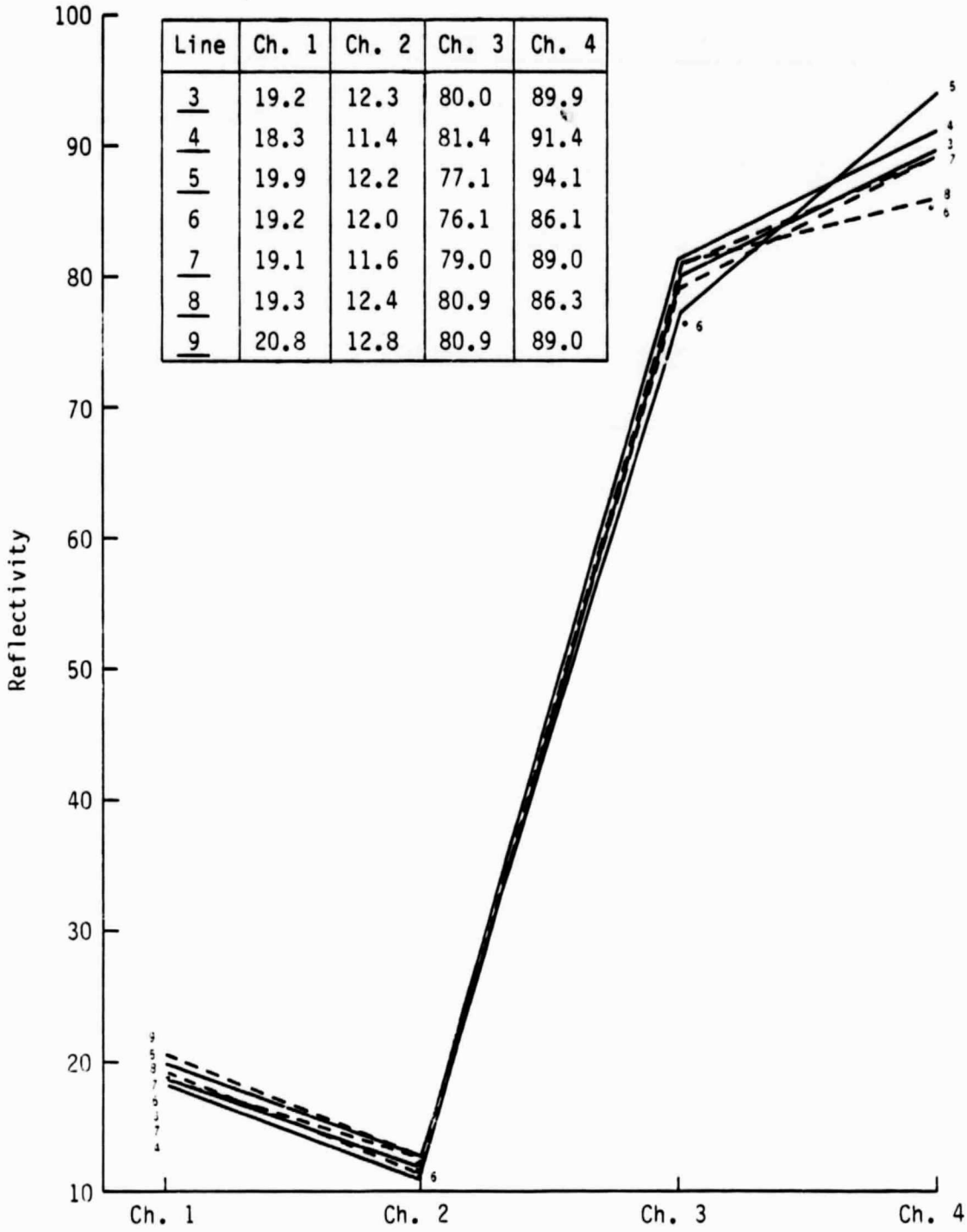

Line	Ch. 1	Ch. 2	Ch. 3	Ch. 4
3	19.2	12.3	80.0	89.9
4	18.3	11.4	81.4	91.4
5	19.9	12.2	77.1	94.1
6	19.2	12.0	76.1	86.1
7	19.1	11.6	79.0	89.0
8	19.3	12.4	80.9	86.3
9	20.8	12.8	80.9	89.0

Figure 2.6-7d.-Mean values of nine-pixel lines for soybean field for acquisition day 78231 (Landsat 3).

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Line	Ch. 1	Ch. 2	Ch. 3	Ch. 4
3	21.9	16.0	73.3	72.9
4	22.6	16.6	72.2	76.2
5	23.4	17.7	71.7	71.3
6	22.9	17.1	74.3	72.9
7	24.4	17.4	73.8	71.8
8	23.6	18.0	72.3	70.4
9	22.2	17.1	71.7	68.2

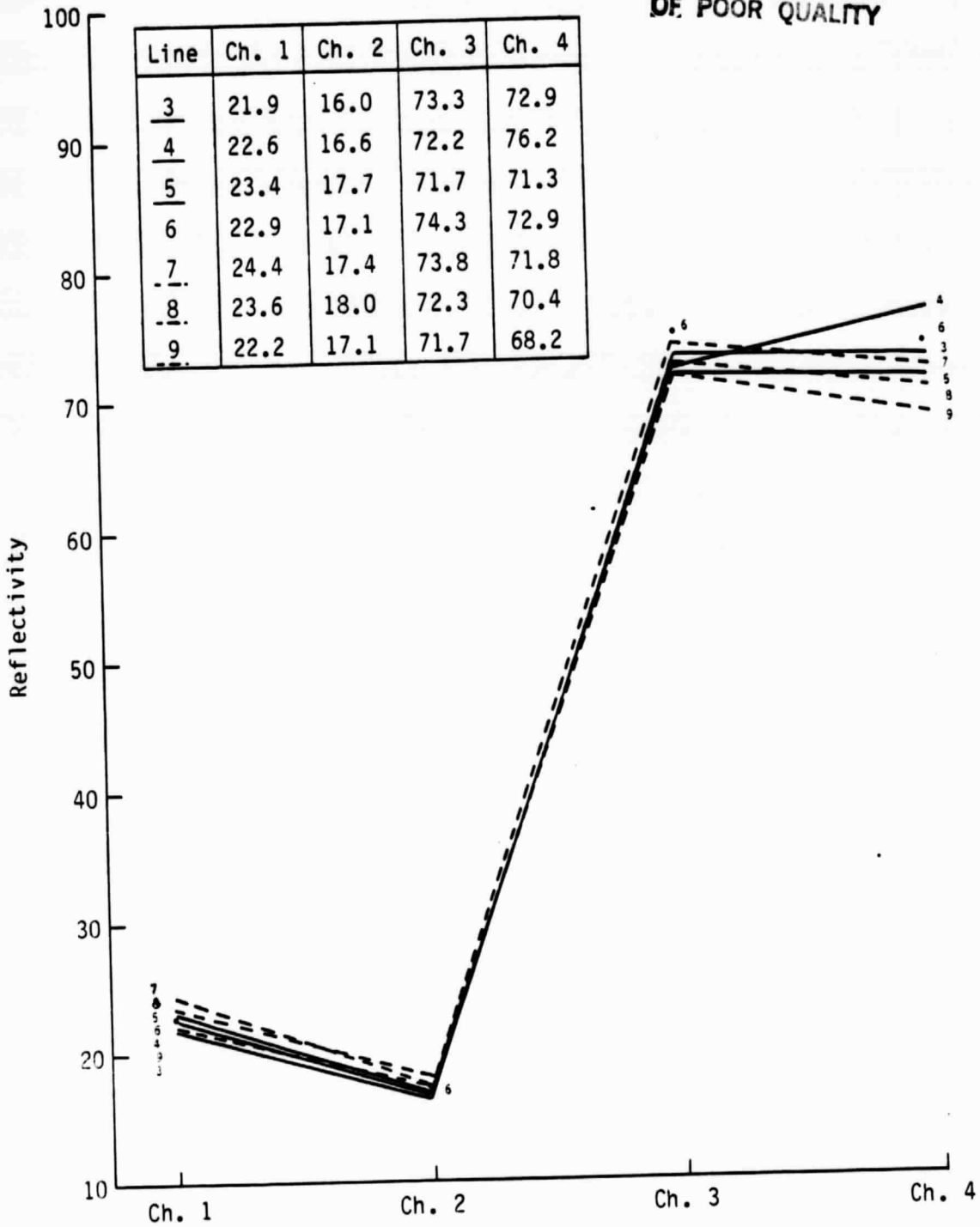

Figure 2.6-7e.-Mean values of nine-pixel lines for soybean field for acquisition day 78249 (Landsat 3).

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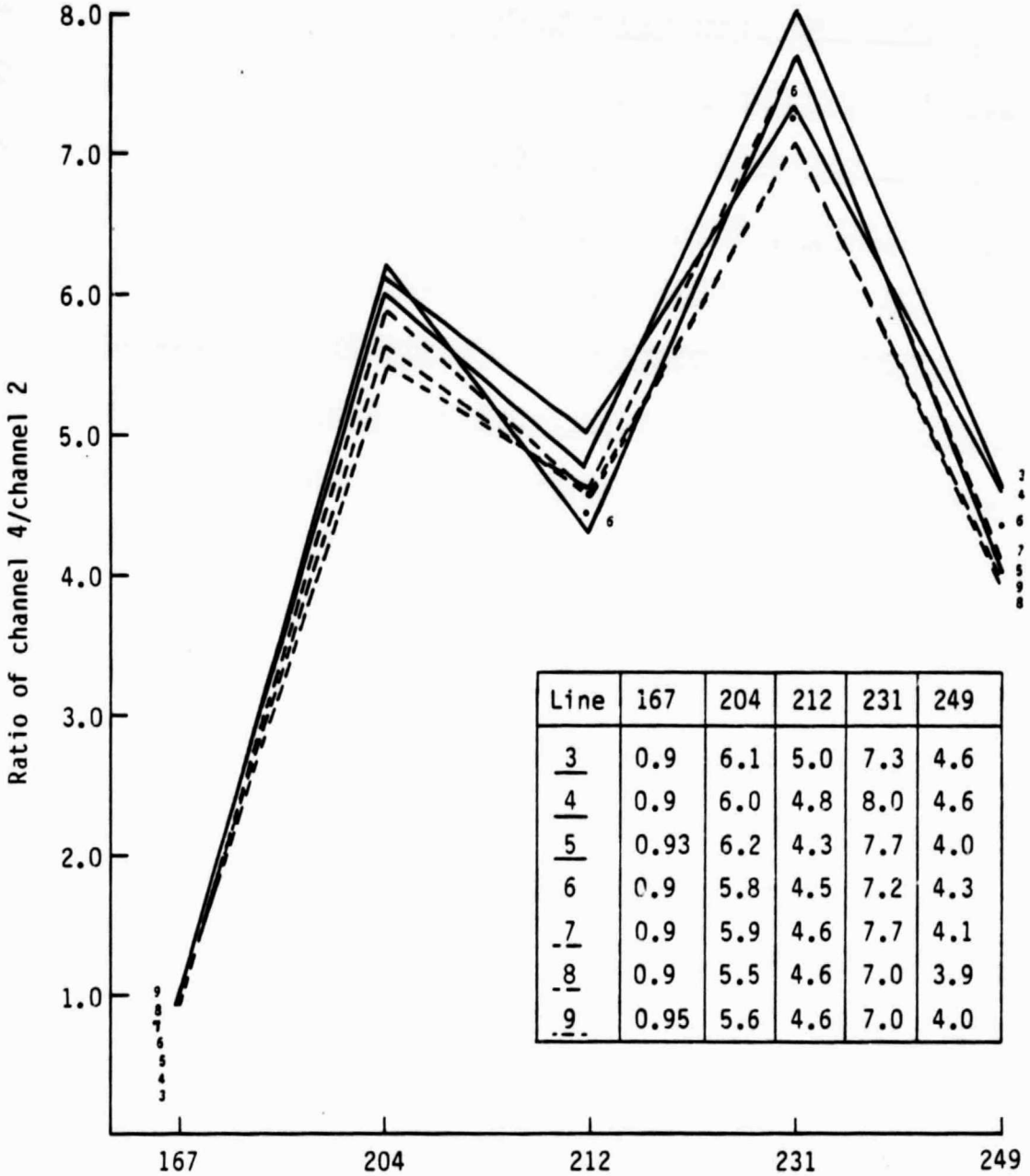

Line	167	204	212	231	249
3	0.9	6.1	5.0	7.3	4.6
4	0.9	6.0	4.8	8.0	4.6
5	0.93	6.2	4.3	7.7	4.0
6	0.9	5.8	4.5	7.2	4.3
7	0.9	5.9	4.6	7.7	4.1
8	0.9	5.5	4.6	7.0	3.9
9	0.95	5.6	4.6	7.0	4.0

Figure 2.6-8. - Mean values of nine-pixel lines for soybean field ratio values of channel 4 divided by channel 2.

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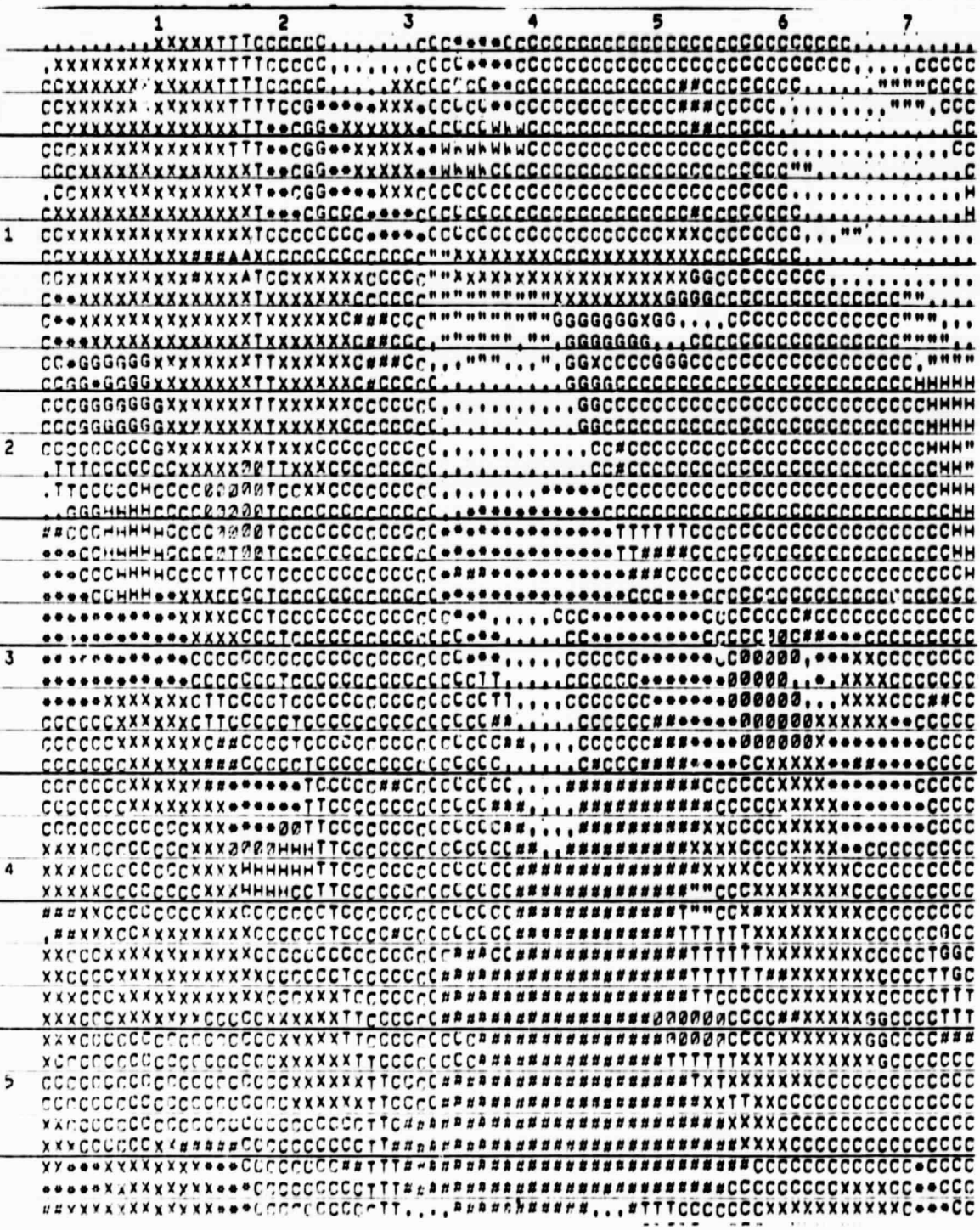

Figure 2.6-9. - AA digitized ground truth map covering block position (801,001) in sample segment 886.

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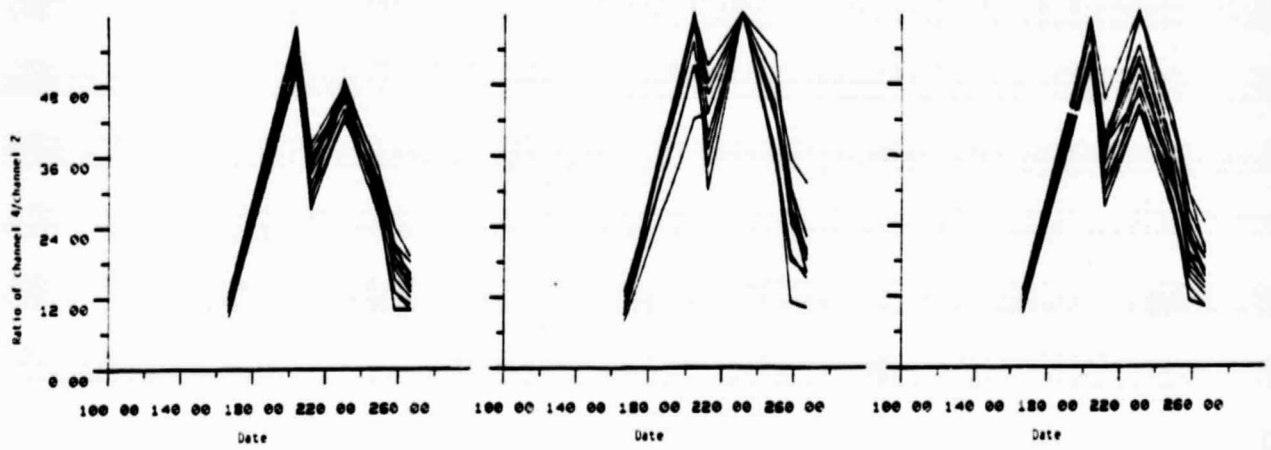
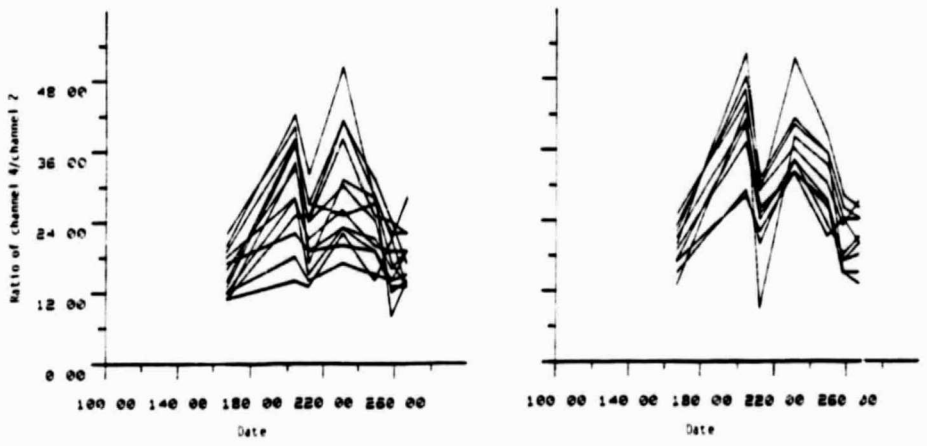


(a) Corn. (b) Soybeans. (c) Summer crop.



(d) Homestead. (e) Trees.

Figure 2.6-10.-Major crop profiles in sample segment 886.

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Crop	78167	78204	78212	78231	78249	78258	78267
3. Summer crops:							
Mean value of data	10.7	55.0	34.8	52.5	33.9	20.3	15.5
Value of fitted curve	10.8	54.7	-	54.5	33.4	22.8	14.3
$A = 1.7$, $\alpha = 29.7$, $\beta = 3.1$, $t_o = 159$, chi-squared fit = 0.2							
4. Trees:							
Mean value of data	19.2	40.8	24.5	37.0	29.5	20.7	20.8
Value of fitted curve	19.5	39.2	-	37.5	29.0	23.9	18.9
$A = 2.3$, $\alpha = 13.7$, $\beta = 1.5$, $t_o = 151 \pm 4$ days, chi-squared fit = 0.3							
5. Homestead:							
Mean value of data	15.1	30.5	21.3	29.8	22.9	17.3	17.5
Value of fitted serve	15.2	29.5	-	28.9	23.3	19.7	16.1
$A = 2.3$, $\alpha = 12.5$, $\beta = 1.3$, $t_o = 154 \pm 7$ days, chi-squared fit = 0.2							

2.6.3 COMPARISON OF GAC-SCALE SIMULATION

Below is a comparison of curve approximations of the block profiles, curve fitted over seven acquisitions. Values A, α, and β are the constants in the approximating curve fitted to the data, and t_o is the estimated emergence date for vegetation.

Block position	A	α	β	t_o
(001,001)	2.0	19.7	2.1	156
(001,069)	1.9	22.6	2.4	157
(001,129)	1.9	20.2	2.1	156
(053,001)	1.9	22.2	2.3	157
(053,069)	2.0	19.6	2.0	156
(053,129)	1.9	21.9	2.3	156
(065,001)	1.8	23.8	2.5	157
(065,069)	2.0	19.4	2.0	156
(065,129)	1.9	22.0	2.3	156

Block signatures are very close in data track and in the equation of the approximating curve. Block position (001,001) serves as a signature representative of the blocks in the segment.

Applying the "vegetative only" filter to block position (001,001) made some difference in signature; 608 of the 3536 potential pixel inputs were eliminated as being nonvegetation. Figures 2.6-11 (a) and (b) are block position (001,001) "all pixel input"; figures 2.6-12 (a) and (b) are "vegetated pixel only input." Note that the LAC input looks different, but the approximating curves are almost identical. In this segment, there was very little non-vegetation, hence, no significant degradation of signature, due to including this in the GAC scale arrays.

2.6.4 LAC-SCALE SIMULATION

Block position (001,001) exhibited the most variability in signature for the individual LAC cells. Figures 2.6-13 (a) through (p) illustrate the data profiles of the 16 cells in the block with major cell content (refer to the digitized ground truth map in section 2.6.2). Cell 1 is a relatively pure soybean cell. A small body of water (34 pixels) is in cell 7; this is too small to alter the cell signature. Cell 8 provides an example of a corn signature harvested on day 258. A cloud and cloud shadow are in cell 9 on day 212. Cell 12 has pasture, oats, and some homestead pixels to average with 50 pixels of summer crop; cell 15, the city of Garland, Iowa, is a relatively pure homestead signature. In this segment, LAC signatures are close to the crop signatures in 2.6.2.

2.6.5 SUMMARY

Sample segment 886 was used to develop the software required for this task and to define the analysis procedure outlined in section 5.3. Based on the experimentation described in this section, segments which varied from sample segment 886 in geographical location, land usage, and agricultural practices were specified for task continuation. The acquisition had a satellite sequence which illustrated the impact of applying an L-3 adjustment; the uniform vegetation cover provided a test of a postulated difference in satellite detector response. The dip in the ratioed data signature was probably due to high cirrus clouds. The scene content of this segment was too homogeneous for exact assessment of the advantages of LAC versus GAC coverage.

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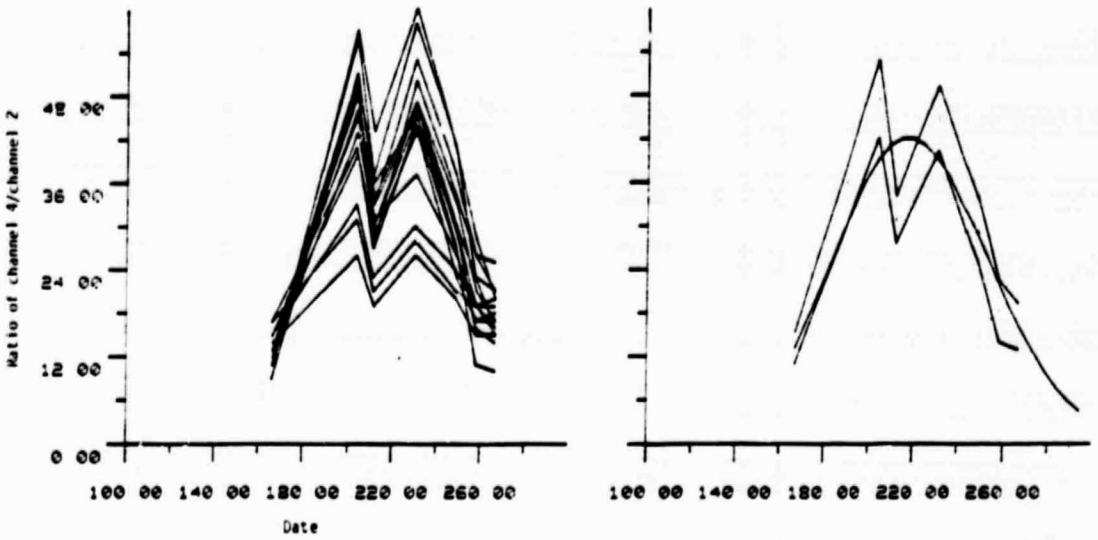
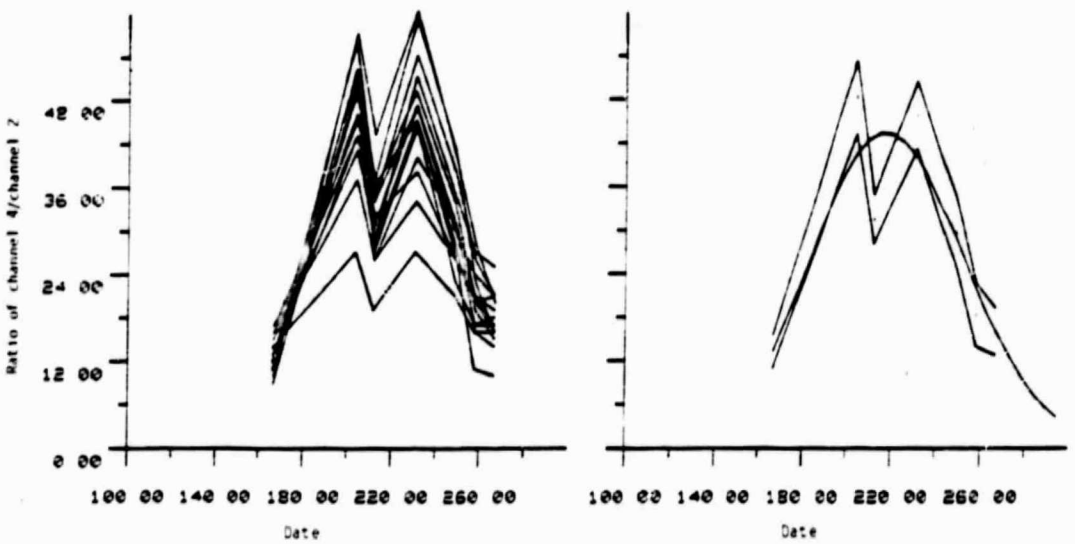


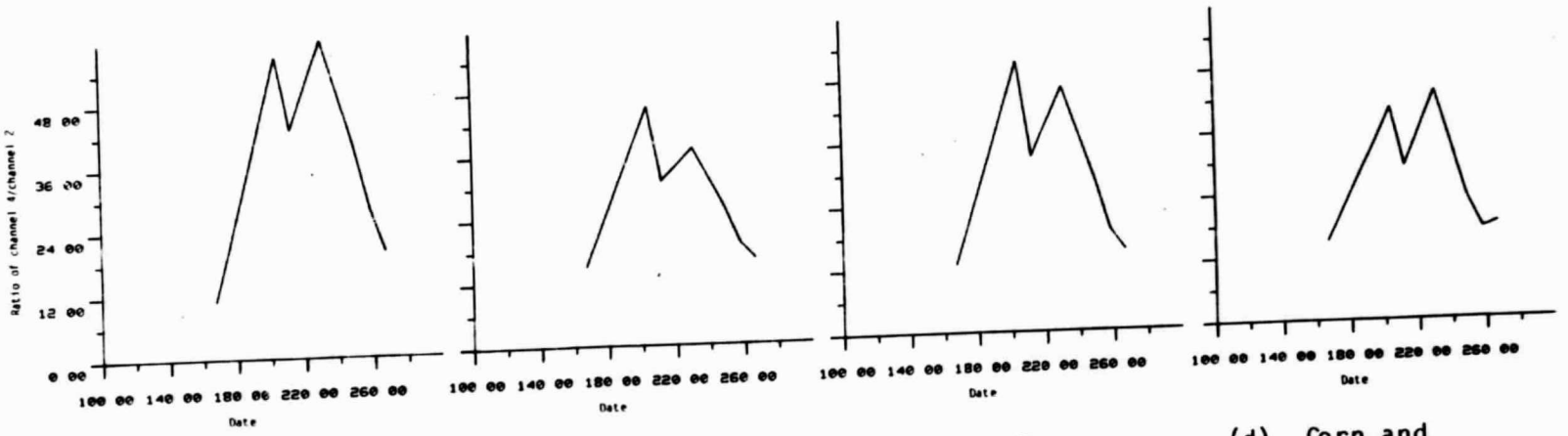
(a) Data. (b) Approximating curve.

Figure 2.6-11.-All pixel input for block position (001,001) in sample segment 886.



(a) Data. (b) Approximating curve.

Figure 2.6-12.-Vegetation only input for block position (001,001) in sample segment 886.

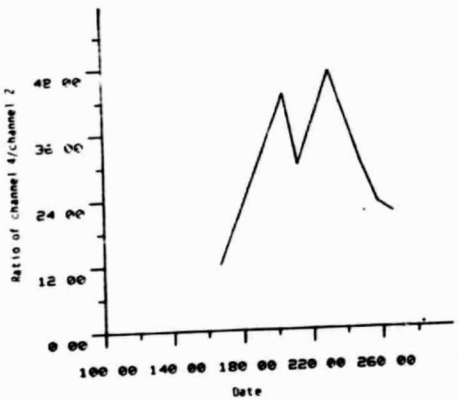


(a) Soybeans.

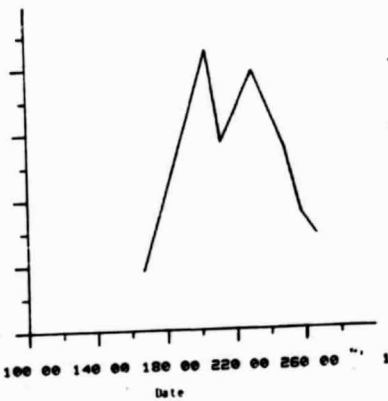
(b) Corn, soybeans, and pasture.

(c) Corn.

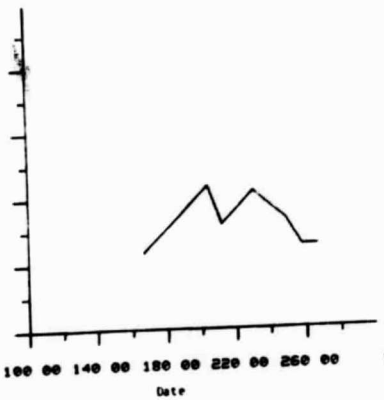
(d) Corn and unidentified.



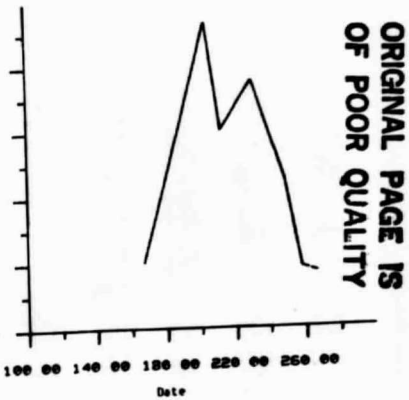
(e) Mixed grains.



(f) Summer crops.



(g) Corn, pasture, water, and unidentified.



(h) Corn.

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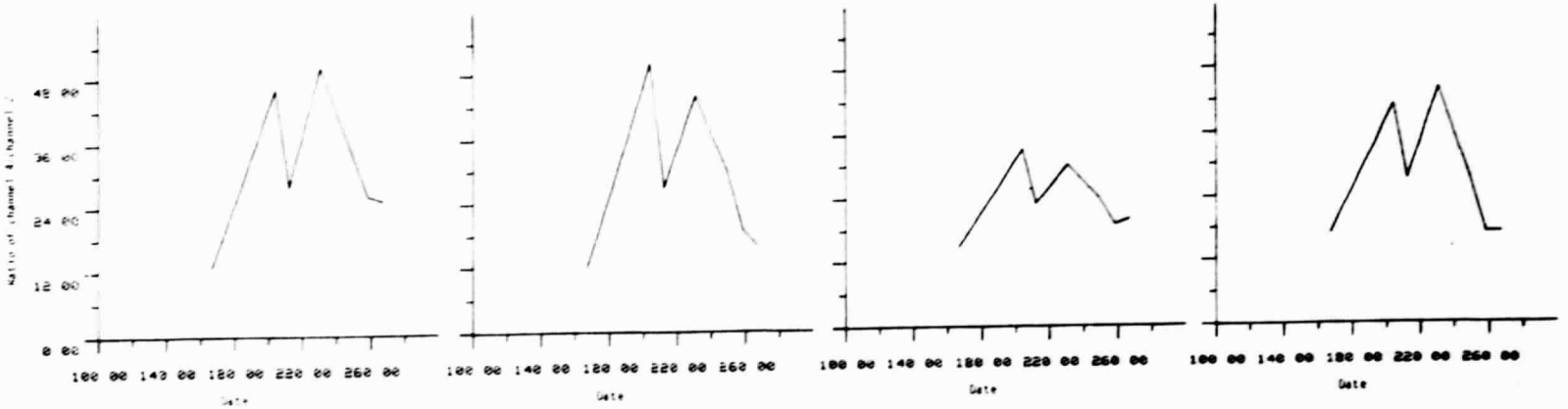
Figure 2.6-13.-The data profiles of the 16 cells in block position (001,001) in sample segment 886.

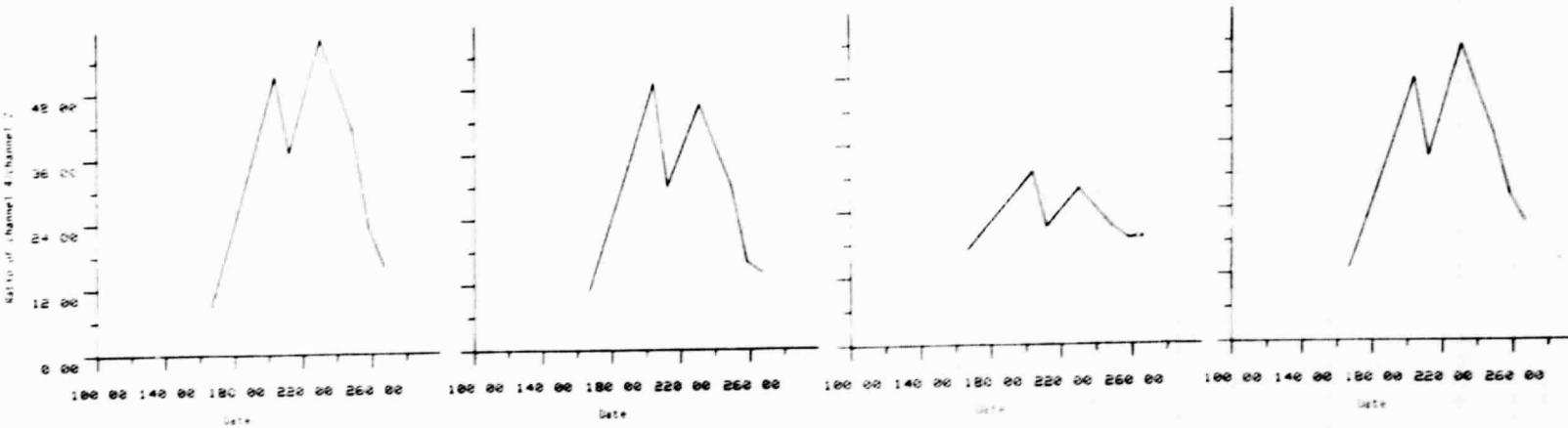


(i) Corn, pasture, and soybeans.

(j) Corn.

(k) Corn, homestead, pasture, and unidentified.

(l) Corn, soybeans, oats and pasture.



(m) Summer crops.

(n) Corn, soybeans, and trees.

(o) Homestead.

(p) Soybeans, corn, and trees.

Figure 2.6-13.- Concluded.

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For this segment, there was little degradation of signature caused by averaging at either the LAC or GAC levels; field size was large enough that fairly "pure" signatures, compared to those generated in section 2.6.2, appeared in both coverages. GAC would probably be adequate for analysis of this segment. It would be possible, however, to generate a misleading estimate of the amount of urban area in the segment using the GAC sampling technique.

Approximation of the data by a curve was done on all the graphs produced and has been very successful when used for classification. For the remaining segments, actual data mean values were graphed in addition to compiling a table of the approximating curve constants. Data variability was so large that approximation resulted in the loss of information of value to the study.

Sample segment 886 had ground truth and acquisitions in crop year 1979 as well as 1978. Comparison multiyear coverage is discussed in section 4.0.

3. COMPARISON OF SIMULATION COVERAGE OVER MULTIPLE GEOGRAPHIC AREAS

The following segments were selected by Dr. V. Whitehead to be processed for geographical expansion of the simulation procedures: sample segment 852, Randolph County, Indiana; sample segment 190, Hinds County, Mississippi; sample segment 185, Traverse County, Minnesota; sample segment 1602, Mountrail County, North Dakota; sample segment 1653, Burleigh County, North Dakota; and sample segment 222, Dawson County, Nebraska. Initial assessments of geographical extension were also done using sample segment 1253, Sequoyah County, Oklahoma, and sample segment 1075, Howard County, Nebraska. Multiyear Landsat coverage was available for the following segments, so these were included in the geographical extension: sample segment 886, Pottawatomie County, Iowa; sample segment 828, Kankakee County, Illinois; sample segment 1924, La Moure County, North Dakota; and sample segment 1725, Flathead County, Montana. Figure 3.1-1 shows the geographical distribution of the 12 segments.

Sample segment 886 is discussed in section 6. Detailed discussions for each of the additional 11 segments appear in the subsections of this section.

3.1 SAMPLE SEGMENT 852, RANDOLPH COUNTY, INDIANA

Sample segment 852, Randolph County, Indiana, had a scene content of 27 percent corn, 31 percent soybeans, and 22 percent pasture and trees. Fields were small, and the scene was heavily vegetated.

The following acquisitions were merged for processing.

Julian date	Landsat	Comments
78097	3	Trees, pasture emergent
78151	3	Trees, pasture, hay, vigorous growth
78160	2	Hay, pasture, trees, some soybeans, vigorous growth
78178	2	Apparent loss of vegetative vigor
78232	2	Segment entirely vigorous growth
78250	2	Some soybeans cut, corn senescent
78268	2	Some soybeans, cornfields still vigorous

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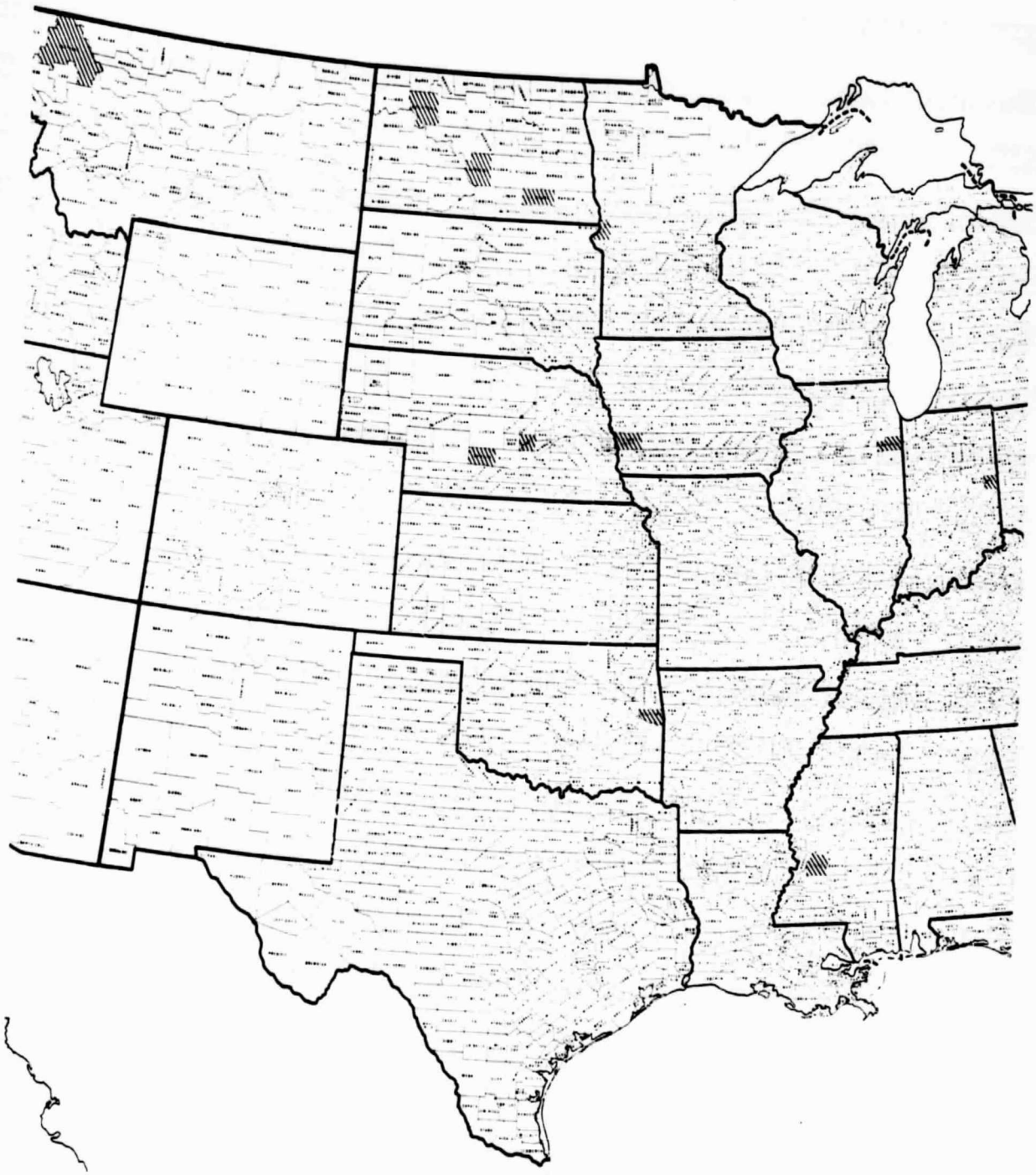

Figure 3.1-1.- Geographical distribution of the sites.

As with day 78212, sample segment 886, ratioed values over all the segment were lower than expected on day 78178. On the PFC film products, the corn signature failed to sequence through this date. Using the software program IMAPLT, corn was graphed for the individual channel input. Figures 3.1-2(a) and (b) illustrate the channel 2 and channel 4 input for corn in block position (001,001). This can be compared with figure 3.1-5(a), the pure corn ratioed signature in block position (001,001). Figures 3.1-3(a) and (b) illustrate the channel 2 and channel 4 input to a soybean field located in block position (001,001). These can be compared to the pure soybean ratioed signature derived from this block position [fig. 3.1-5(b)].

IMAPLT graphs were also made for the block positioned at (001,001). Figure 3.1-4(a) gives the channel 2 input for the 45 pixels of the simulated GAC-scale block, and figure 3.1-4(b) gives the channel 4 input. Figure 3.1-4(c) is the ratioed block signature for comparison. The decrease in data values may reflect an agronomic factor such as hail damage.

Major ground cover in the segment was corn, soybeans, and trees. These components are illustrated in figures 3.1-5(a), (b), (c), and (d). A combined summer crop signature (corn and soybeans) is shown in 3.1-5(c).

The following chart shows a comparison of the block profiles for this segment taken from the curve fitted to seven acquisitions.

Block position	A	α	β	t_0
*(001,001)	2.2	13.6	1.4	153
*(001,069)	2.5	9.8	1.0	148
(001,129)	2.4	10.1	1.0	149
*(053,001)	2.1	16.9	1.7	157
*(053,069)	2.6	7.1	0.7	146
(053,129)	2.7	6.3	0.7	141
(065,001)	2.1	18.3	1.9	156
(065,069)	2.7	7.2	0.7	145
(065,129)	2.8	5.7	0.6	140

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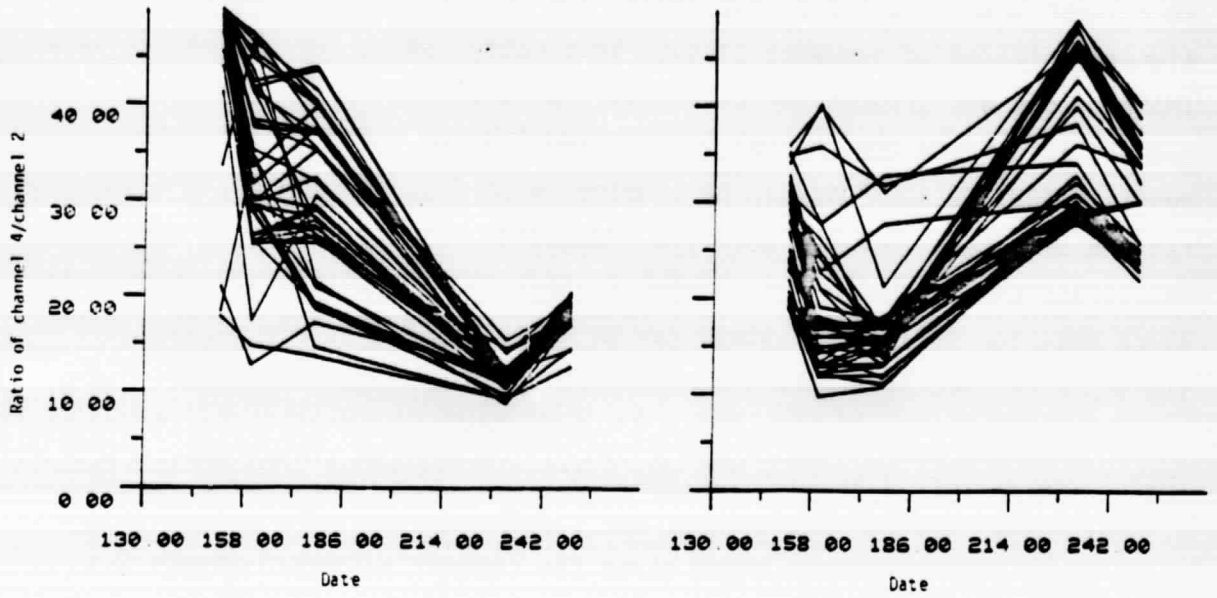
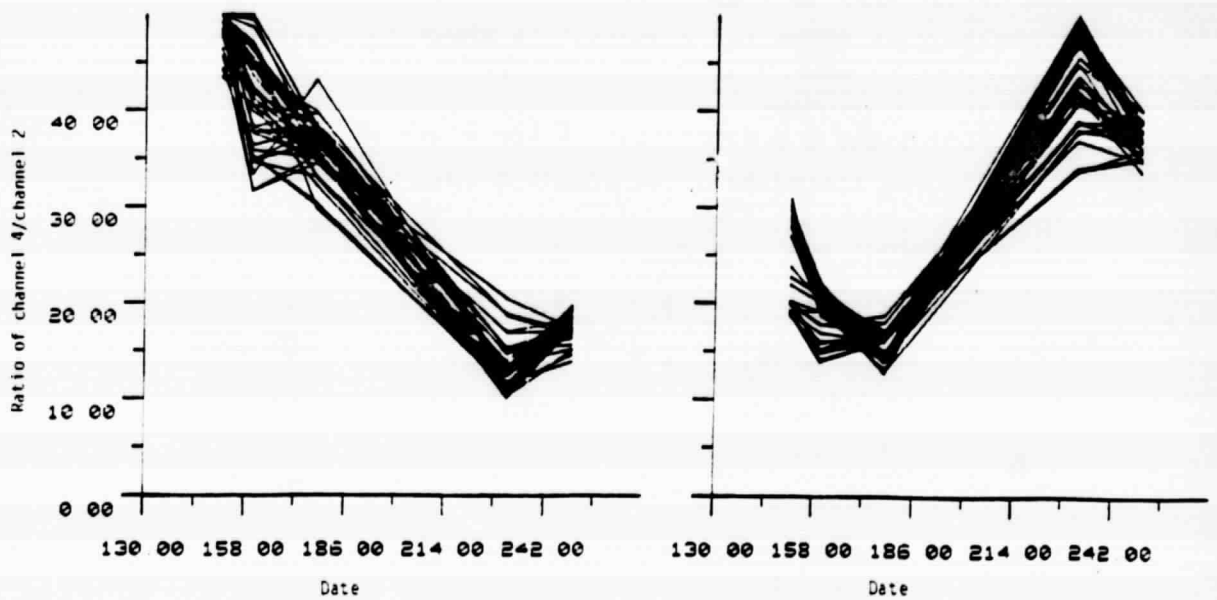


(a) MSS channel 2. (b) MSS channel 4.

Figure 3.1-2.- Corn in sample segment 852.



(a) MSS channel 2. (b) MSS channel 4.

Figure 3.1-3.- Soybeans in sample segment 852.

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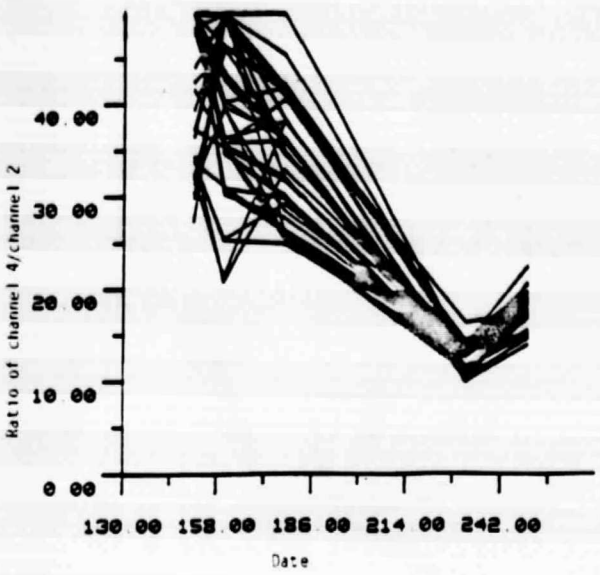
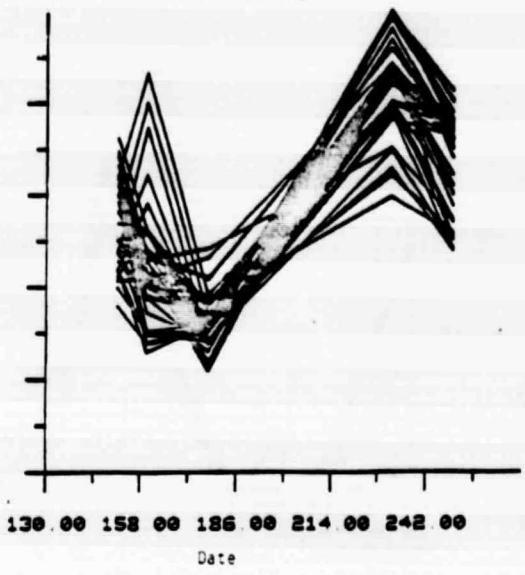
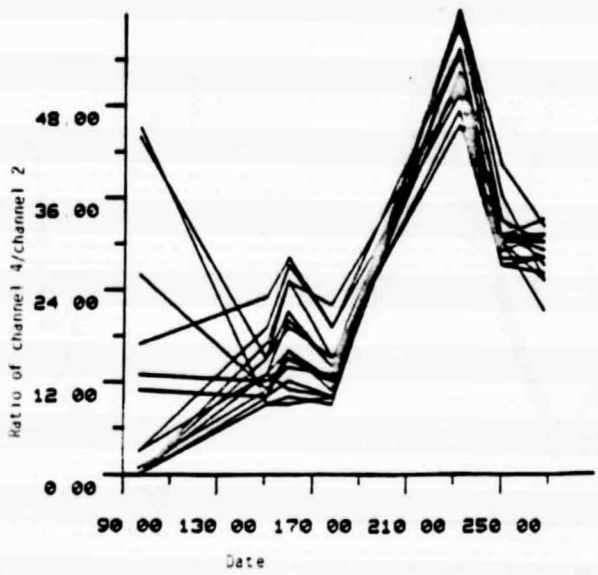


(a) MSS channel 2.



(b) MSS channel 4.



(c) Ratio of channel 4/channel 2.

Figure 3.1-4.- Block position (001,001) in sample segment 852.

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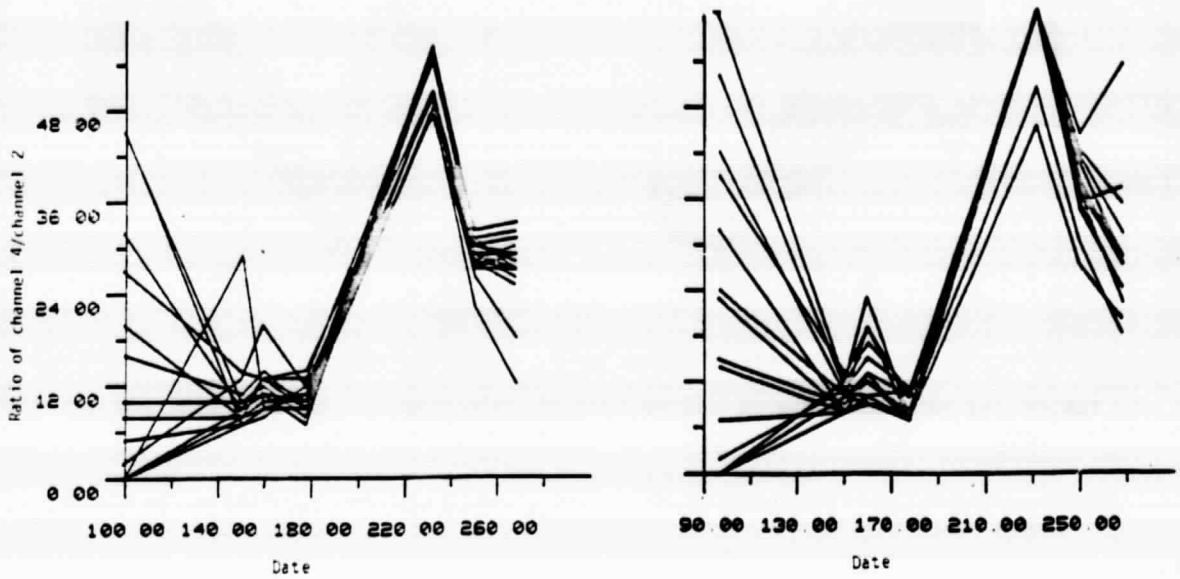
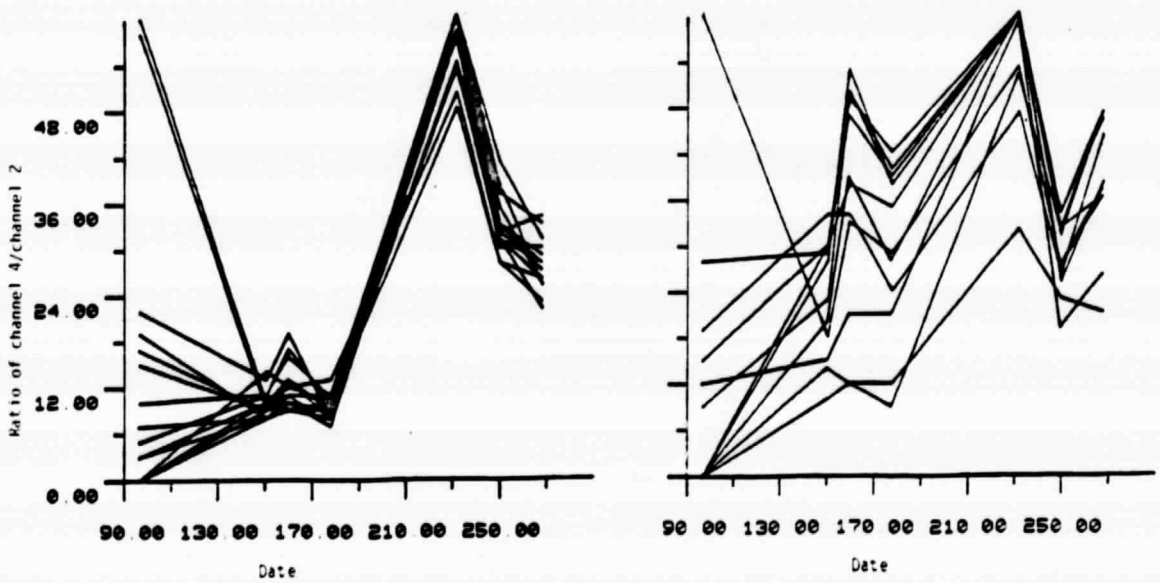


(a) Corn.

(b) Soybeans.



(c) Summer crop.

(d) Trees.

Figure 3.1-5.- Major crop profiles of sample segment 852.

Parameters above indicate a greater variety of data signatures than are apparent on the graphs; data graphs over this segment appear to be similar. Figure 3.1-6 is a composite of the mean values of the data for the block positions indicated by asterisks above.

Block position (001,069), illustrated in figure 3.1-7(a), can be considered a representative profile for the segment. Figures 3.1-7(a) and (b) illustrate the input for all pixels at (001,069) and figures 3.1-8(a) and (b) illustrate the vegetation only profiles. The curve fit is to five acquisitions only: 78151, 78160, 78232, 78250, and 78268.

Very little difference in signature was caused by removing nonvegetation pixels from input. Applying the nonvegetation filter removed 408 of the 3536 pixels used in the all-input graph.

Figure 3.1-9 is the AA digitized ground truth map covering block position (001,001). Figures 3.1-10(a) through (p) illustrate the data profiles of 16 cells in the block position at (001,001) with major cell content.

Summary

The vegetation data pattern of this segment was unusual and difficult to approximate with a curve. The segment has small fields and is almost entirely vegetation. A summer crop signature dominates the LAC-scale simulation and the GAC scale and reflects ground cover. Both LAC and GAC scale profiles are similar to the component signatures. The GAC scale profiles are stable over the segment and would be adequate for segment analysis. An apparent aborted vegetation green-up on day 78178 is indicated by a decrease in reflectivity.

3.2 SAMPLE SEGMENT 190, HINDS COUNTY, MISSISSIPPI

Sample segment 190, Hinds County, Mississippi, had a scene content of 7 percent corn, 9 percent soybeans, 12 percent cotton, 20 percent pasture, and 26 percent trees. Nineteen percent of the segment was not identified ground truth; most of this appeared to be cropland.

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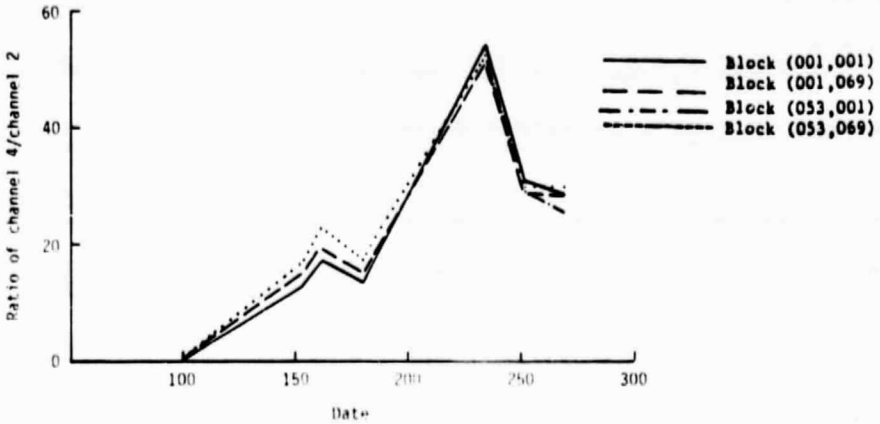
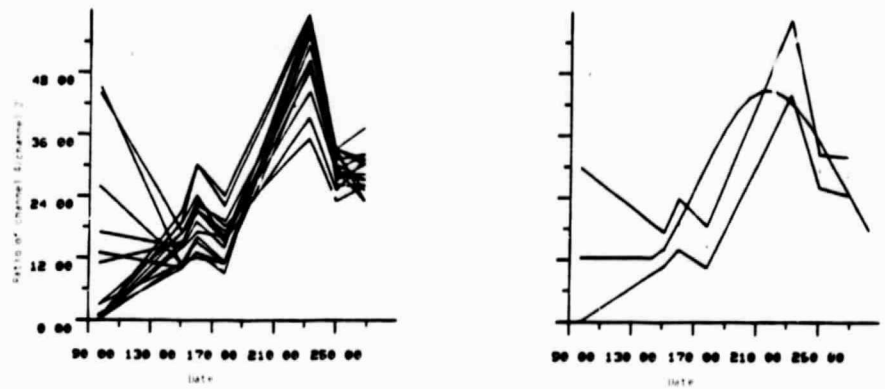
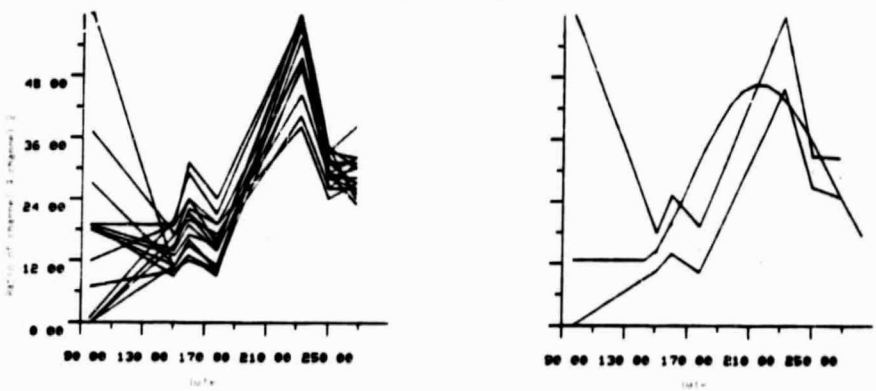


Figure 3.1-6.- Comparison of mean values of block positions (001,001), (001,069), (053,001), and (053,069) in sample segment 190.



(a) Data. (b) Approximating curve.

Figure 3.1-7.- All pixel input for block position (001,069) in sample segment 852.



(a) Data. (b) Approximating curve.

Figure 3.1-8.- Vegetation only input in block position (001,069) in sample segment 852.

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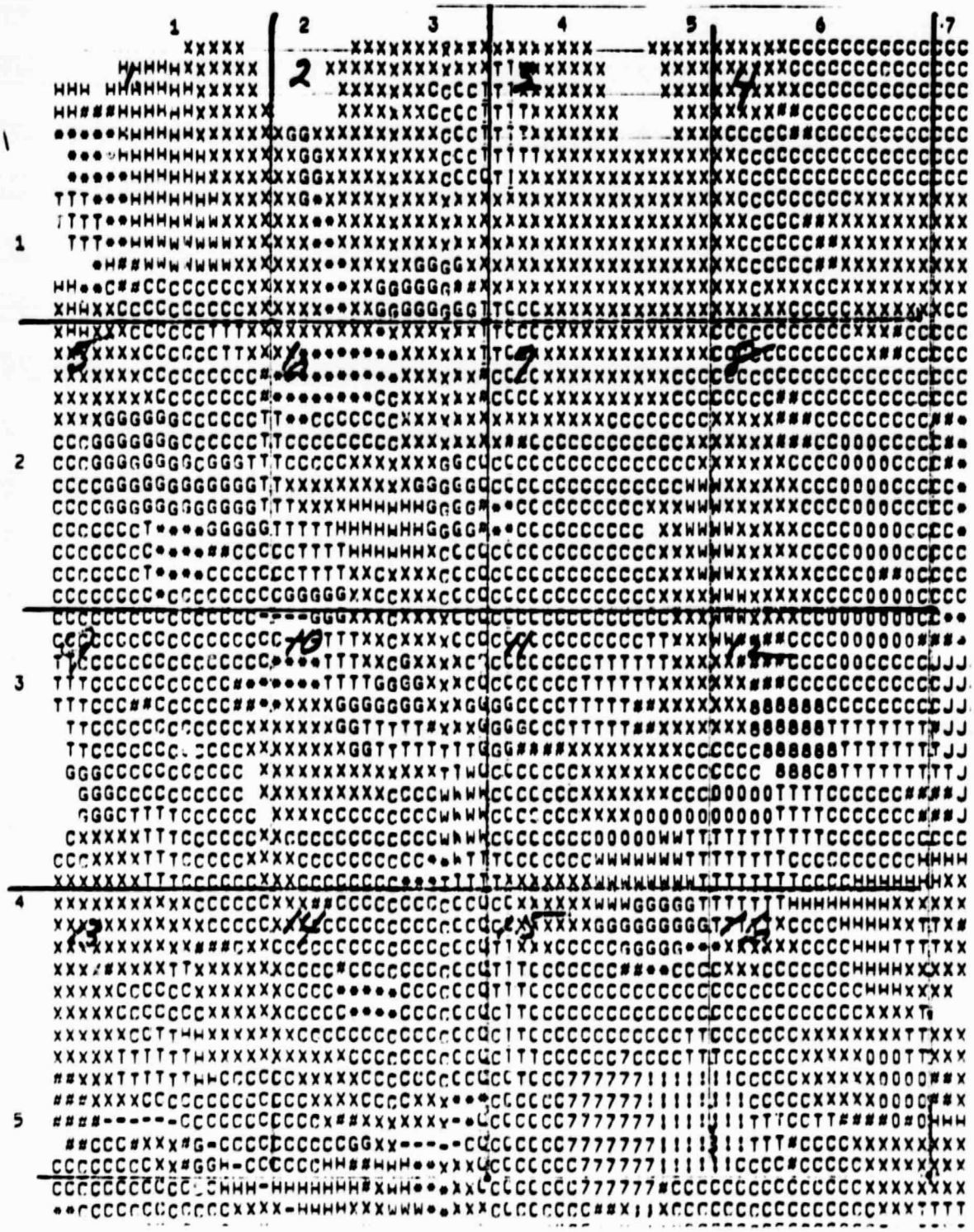
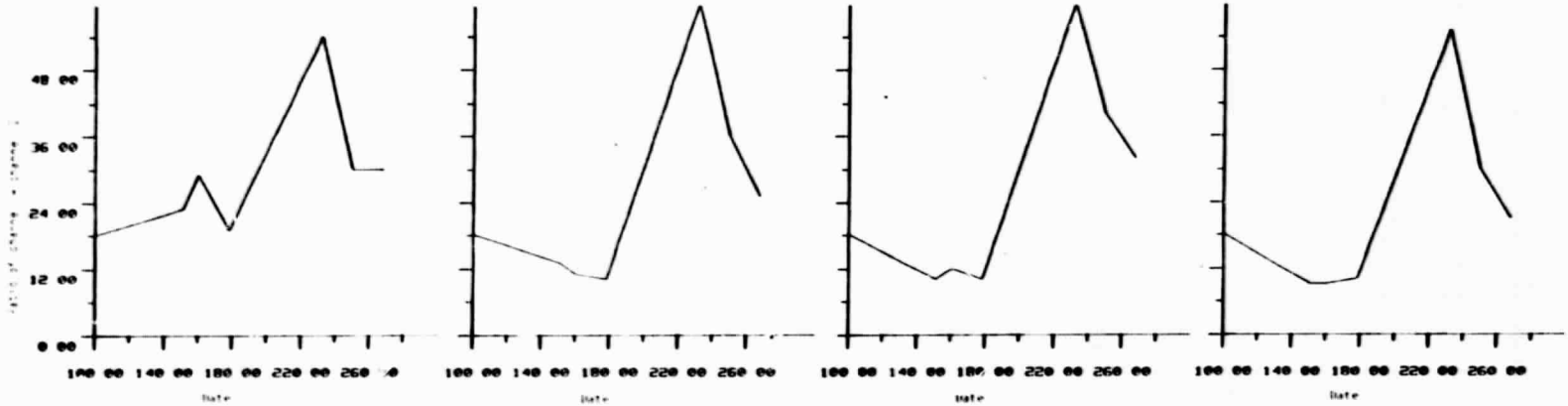
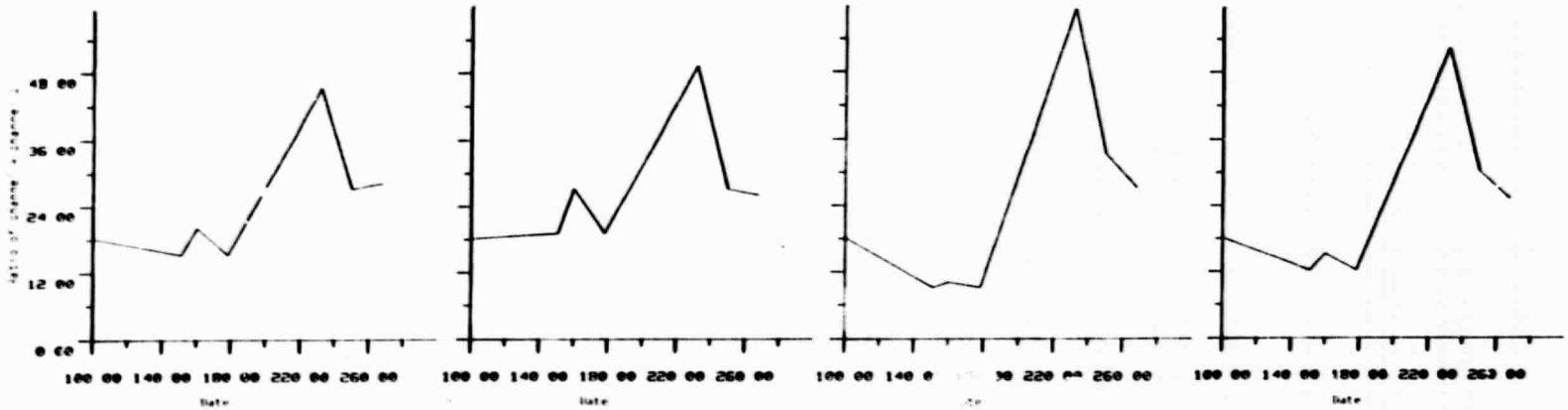


Figure 3.1-9.- The AA digitized ground truth map covering block position (001,001) of sample segment 852.



(a) Hay and soybeans. (b) Soybeans. (c) Soybeans. (d) Corn and soybeans.



(e) Corn, grass, and soybeans. (f) Mixed grains. (g) Corn and soybeans. (h) Corn and soybeans.

Figure 3.1-10.- The data profiles of the 16 cells in block position (001,001) of sample segment 852.

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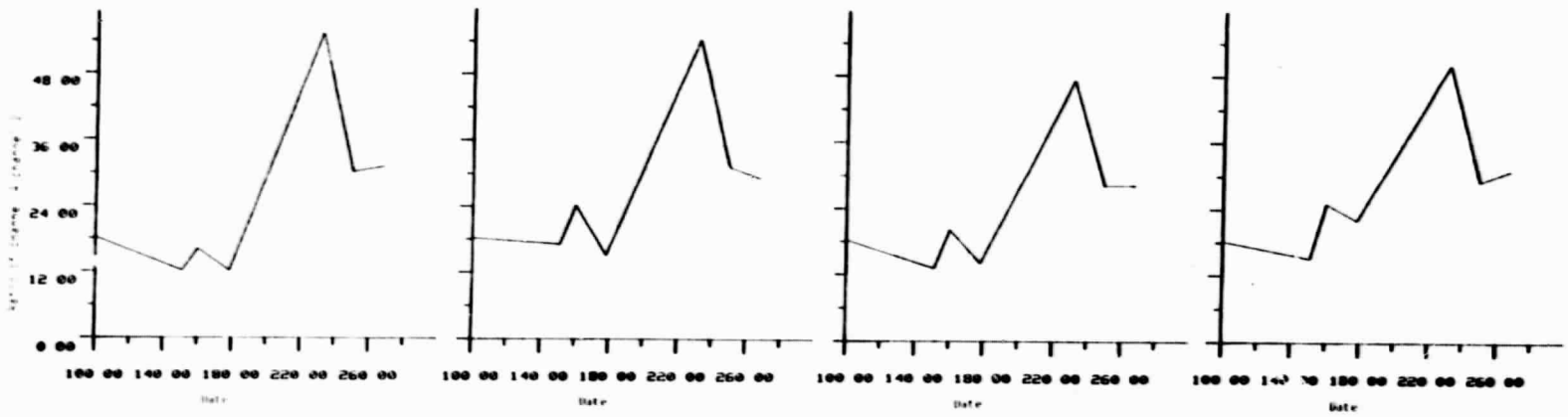
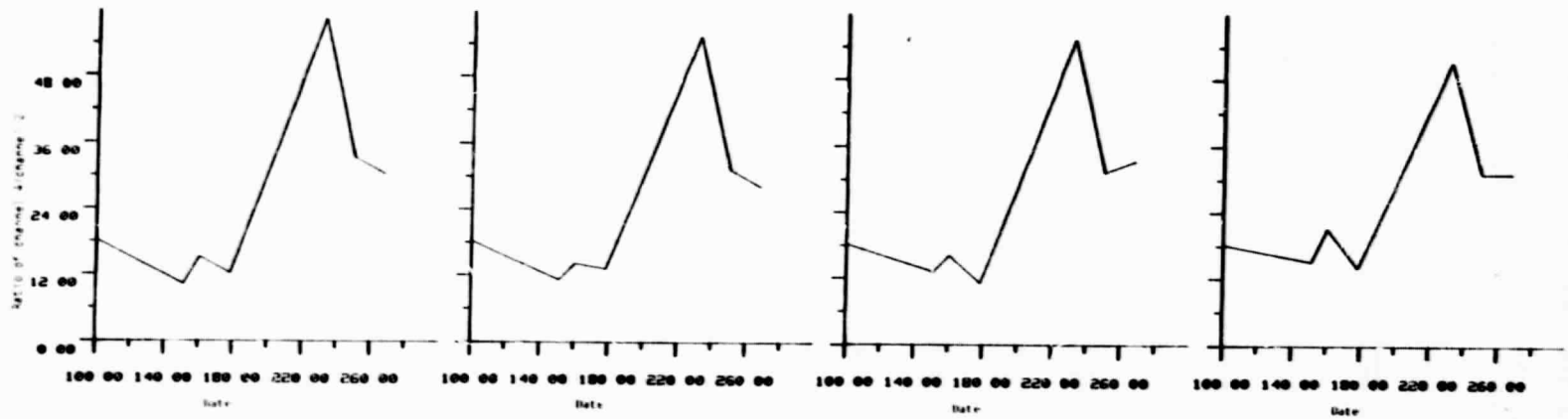


(i) Corn. (j) Mixed grains. (k) Summer crops. (l) Corn and trees.



(m) Summer crops. (n) Corn. (o) Corn. (p) Mixed

Figure 3.1-10.- Concluded.

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Acquisition distribution for this segment is poor, and there is a gap in coverage between Julian day 78135 and 78207. The following acquisitions were used in creating the merged image file.

Julian date	Landsat	Comments
78117	3	Trees, pasture in vigorous growth
78135	3	Fields cleared
78207	3	Emergence of summer crops, including cotton
78216	2	Pasture, trees senescent; summer crops vigorous
78234	2	
78243	3	Slight haze over line 0-10, pixel 0-30
78279	3	Corn and cotton senescent

There is no single vegetation cycle apparent on the film products. The geographical location produces a long growth season that is different from the growth season of more northern regions. Crop signatures in this site tend to describe reverse curves from the signatures of the same crop in other segments; this was probably caused by the difference in relative crop stage relative calendar. On day 78117, tree and pasture areas were in vigorous growth, but on day 78207, these areas were senescent. This described a reverse curve from areas of different vegetation within the segment. Sometimes curve fitting was impossible; on the GAC level, curve approximation is always unrepresentative of the data.

Cotton was a confusion crop with corn in this segment. Also, ground truth corn for some areas did not follow the usual cycle for a summer crop. Some fields planted with corn were bare soil on day 78117, and emerged on day 78135; a very weak growth signature appeared until day 78234, when the fields appeared to be cleared. For other corn, emergence was evident on day 78207 and subsequently exhibited a vigorous signature, then was senescent on day 78279.

Major ground cover in this segment was cotton, pasture, trees, and corn. These are illustrated in figures 3.2-1(a) through (d). From these graphs of the data, it is evident that corn exhibited a profile like cotton or pasture.

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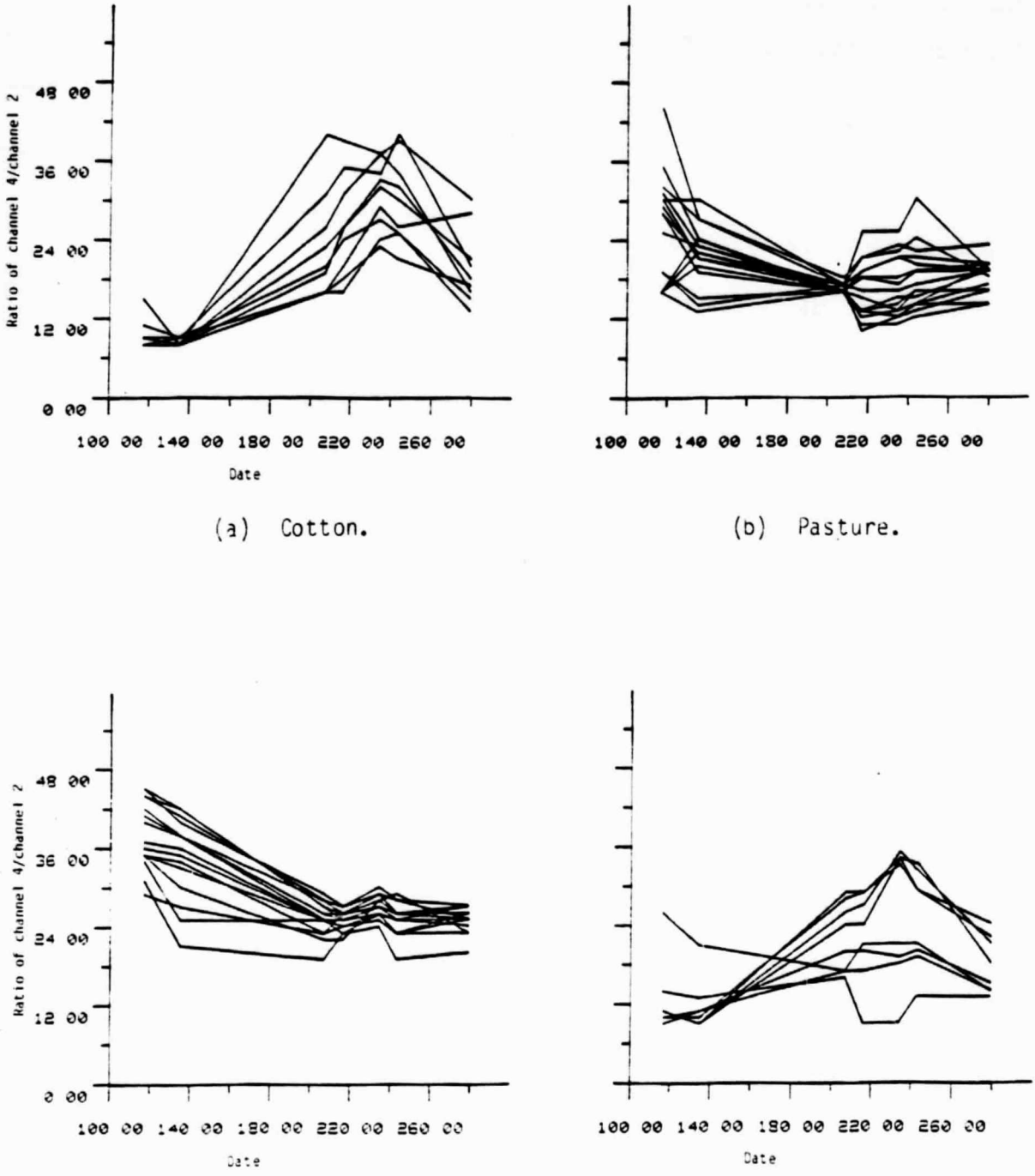

(a) Cotton.

(b) Pasture.

(c) Trees.

(d) Corn.

Figure 3.2-1.- Major crop profiles of sample segment 190.

Two corn profiles were evident on the PFC products as well as the graphs, and these are illustrated in figures 3.2-2 and 3.2-3. Figure 3.2-2 shows pure corn pixels in block position (001,001); figure 3.2-3 shows pure corn pixels in block position (065,129).

Below is a comparison of the block profiles for this segment taken from the curve fitted to seven acquisitions.

Block position	A	α	β	t_o
*(001,001)	2.2	2.5	0.2	106 ± 8 days
*(001,069)	3.2	-1.2	0.3	617 ± 219 days
(001,129)	2.6	1.0	0.1	83 ± 2 days
*(053,001)	2.9	0.3	0.0	51 ± 1 day
*(053,069)	3.1	-0.7	-0.1	435 ± 1007 days
(053,129)	2.5	0.5	0.0	85 ± 881 days
(065,001)	2.7	-0.0	-0.1	7 ± 881 days
(065,069)	2.9	-1.4	-0.3	315 ± 3032 days
(065,129)	2.6	-0.0	-0.0	9 ± 19 days

Figure 3.2-4 is a graph of the mean values of the data for the block positions indicated by asterisks above.

The curve fitting of the GAC profiles generated on this segment was totally unsatisfactory. Most blocks generated a line fit caused in part by two clear signature types: trees/pasture with cotton/corn. Block position (001,129), figure 3.2-5(a), is typical. Applying the vegetation filter, figures 3.2-5(a) through 3.2-6(b), to input on this block removed 678 of the 3536 pixels as nonvegetation; the data pattern was not changed very much when non-vegetation pixels were removed from input the graphs.

Figure 3.2-7 is the AA digitized ground truth map covering block position (001,129). Standard AA coding for 1978 used a C for both corn and cotton. A code of Z for cotton is used in figure 3.2-7. Other symbols are x for soybeans (with T, K, %, !, 0 as special fields of soybeans), * for pasture, T for trees, 1 for cornfields, and "unidentified" for blank areas. A LAC simulation was generated on block position (001,129) to avoid a larger area of 'unidentified'

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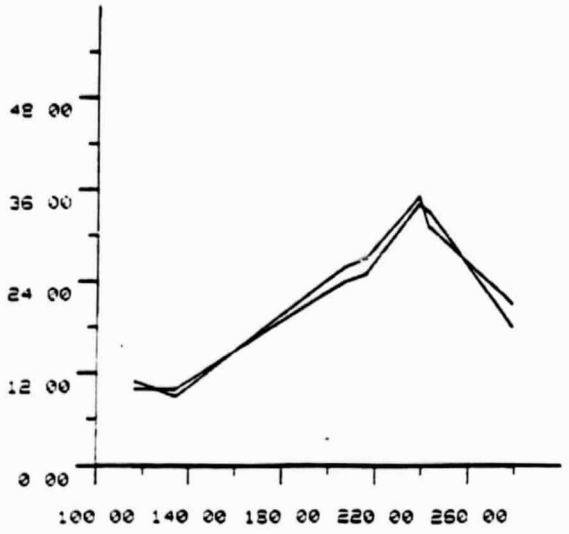

Figure 3.2-2.- Pure corn pixels in block position (001,001).

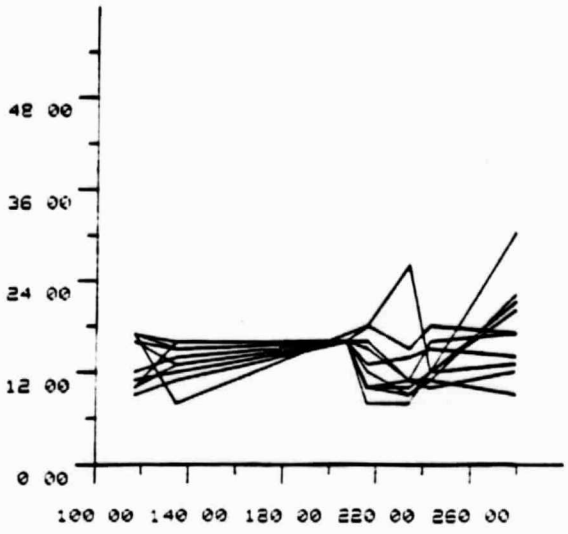

Figure 3.2-3.- Pure corn pixels in block position (065,129).

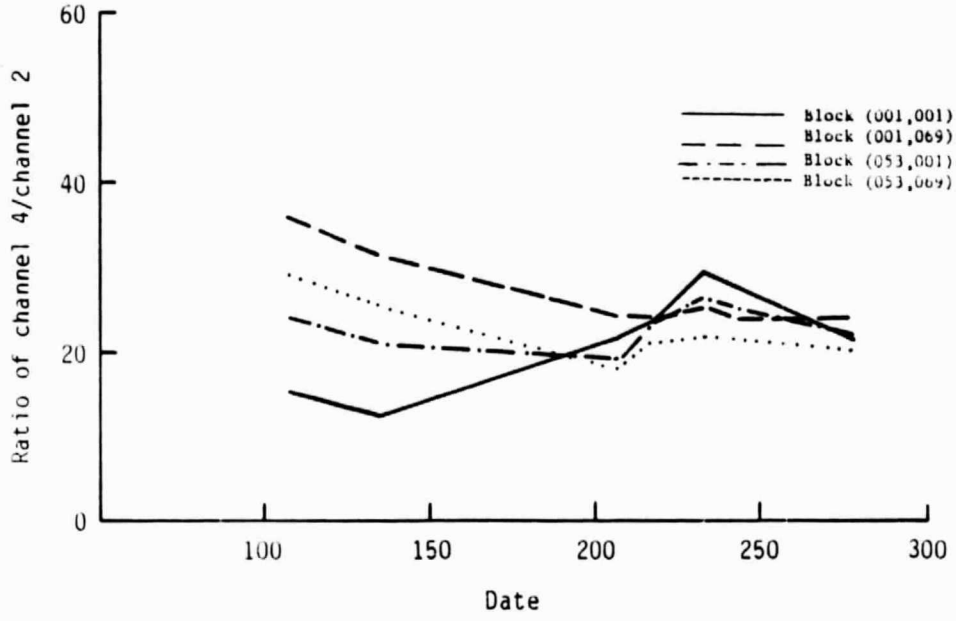

Figure 3.2-4.- Comparison of mean values of block positions (001,001), (001,069), (053,001), and (053,069) in sample segment 190.

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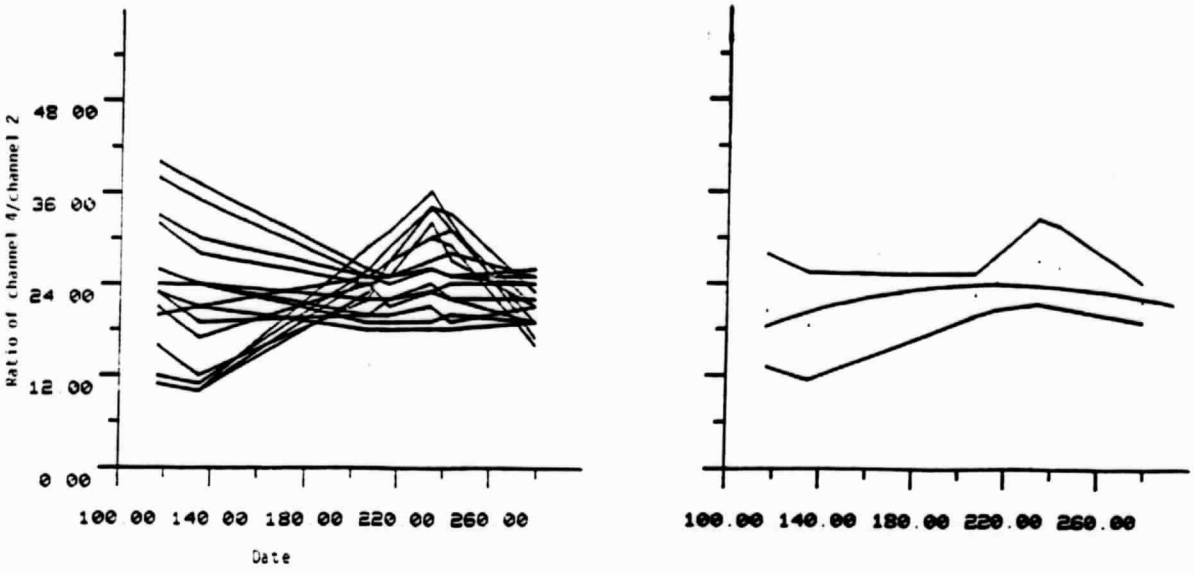
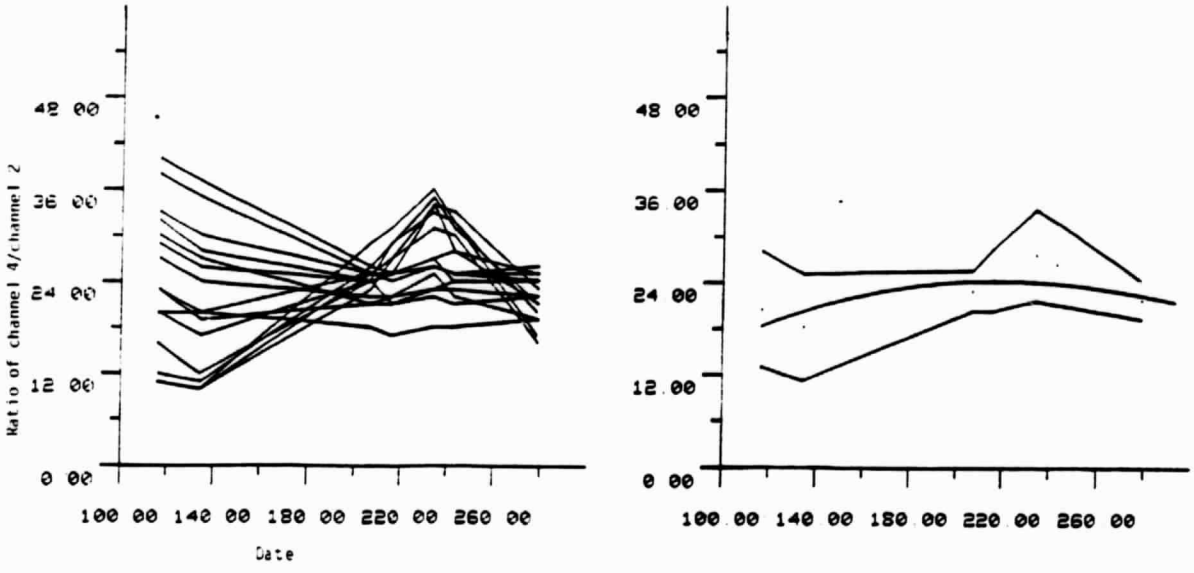


(a) Data. (b) Approximating curve.

Figure 3.2-5.- All pixel input for block position (001,129) in sample segment 190.



(a) Data. (b) Approximating curve.

Figure 3.2-6.- Vegetation only input in block position (001,129) in sample segment 190.

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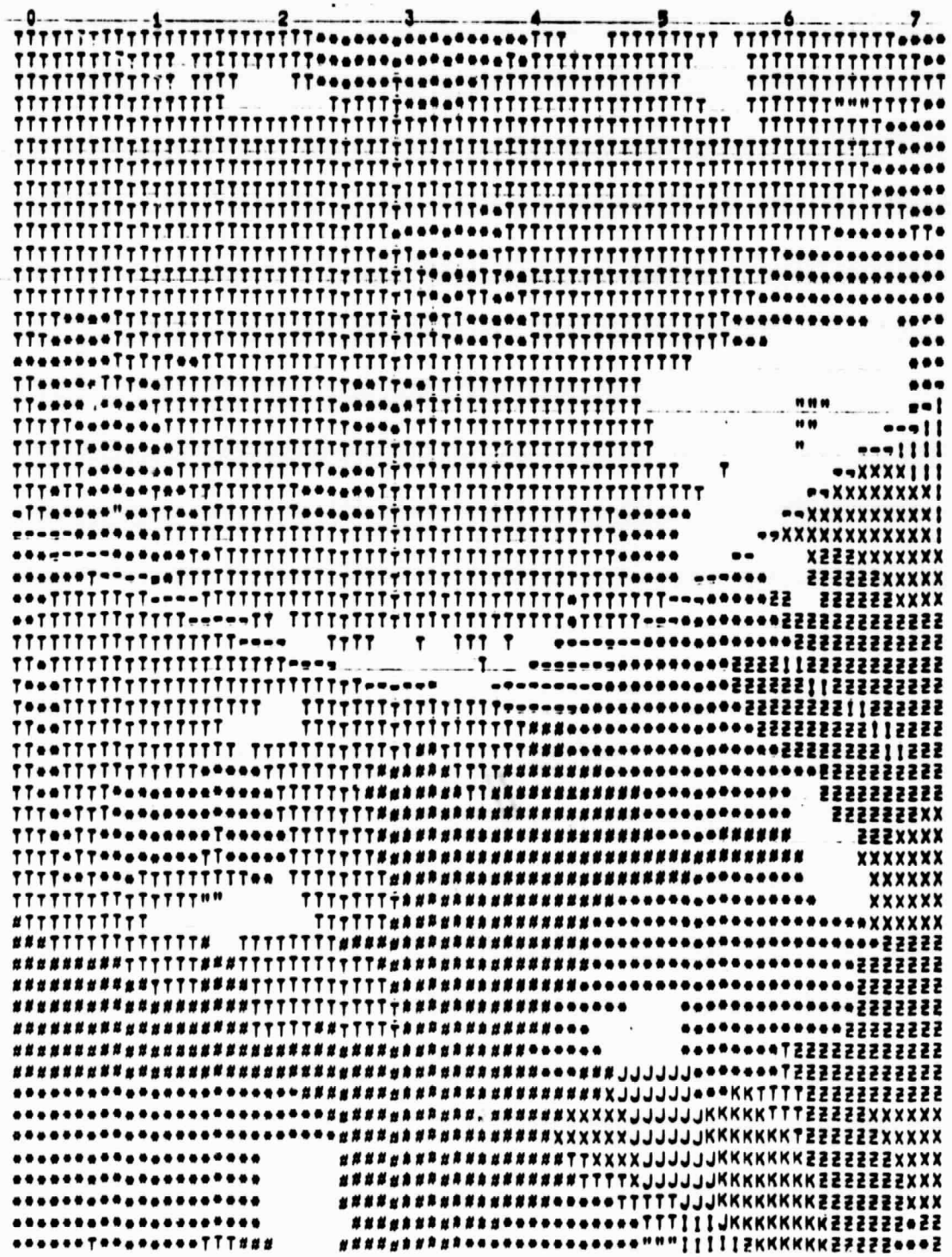

Figure 3.2-7.- The AA digitized ground truth map covering block position (001,129) in sample segment 190.

in block position (001,001) and to obtain a reasonable sampling of segment contents.

Making a choice of a block on which to simulate LAC was difficult. For example, block position (001,001) was largely unidentified by ground truth; at (001,069) the area was predominately trees, and at (001,129) there was a small amount of corn and a relatively large concentration of soybeans. Missing identification was a problem throughout the segment. Figures 3.2-8(a) through (p) illustrate the data profiles of the 16 cells with major cell content in block position (001,129).

Summary

This segment had a number of distinct profiles that caused confusion when this GAC simulation was used. Large areas average such different signatures that curve approximation fails or describes a straight line. Degradation of LAC signatures is not so severe. Field size in this segment is large, so relatively pure signatures occur at the LAC level over most of the segment.

The long growing season in this geographical area caused the set of acquisitions selected for processing to be inadequate for representing a growth curve for all the vegetation in the segment. Cotton is a confusion crop with corn in this segment, and much of the corn exhibits an unusual signature.

3.3 SAMPLE SEGMENT 185, TRAVERSE COUNTY, MINNESOTA

Sample segment 185, Traverse County, Minnesota, had a scene content of 6 percent corn, 7 percent soybeans, 21 percent sunflowers, and 27 percent spring wheat. Fifteen percent of the segment was not identified by ground truth, the area was primarily cropland.

Acquisition coverage was very good. The following acquisitions were merged for processing.

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(a) Trees and pasture.

(b) Trees.

(c) Trees and pasture.

(d) Pasture, trees, and corn.

(e) Trees.

(f) Trees and unidentified.

(g) Soybeans and unidentified.

(h) Cotton and unidentified.

Figure 3.2-8.- The data profiles of the 16 cells in block position (001,129) in sample segment 190.

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(i) Trees and homestead.

(j) Pasture and cotton.

(k) Cotton.

(l) Cotton and soybeans

(m) Homestead.

(n) Pasture and soybeans.

(o) Cotton and soybeans.

(p) Cotton and soybeans

Figure 3.2-8.- Concluded.

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Julian date	Landsat	Comments
78133	2	Pasture, hay vigorous
78169	2	Spring grains vigorous, sunflowers bare
78197	3	Grains senescent, sunflowers vigorous
78214	3	Grains ripe or harvested, sunflowers vigorous
78224	2	Sunflowers senescent
78250	3	
78287	3	Sugarbeets, alfalfa and rest of crops vigorous

This segment had spring grains, summer crops, and sunflowers. Field size was good. Major scene components are illustrated in figures 3.3-1(a) through (d).

The chart below compares the block profiles for this segment.

Block position	A	α	β	t_o
*(001,001)	2.7	4.6	0.6	138
*(001,069)	2.8	5.7	0.8	139
(001,129)	2.5	7.2	0.8	151
*(053,001)	2.7	5.5	0.7	138
*(053,069)	2.8	5.8	0.8	136
(053,129)	2.7	5.4	0.7	137
(065,001)	2.7	4.8	0.7	135
(065,069)	2.8	5.3	0.7	135
(065,129)	2.7	5.5	0.7	136

Figure 3.3-2 shows the mean values of the data for the block positions indicated by the asterisks. The mean values were very close, and any of the block positions could be considered a typical block signature; block position (065,001), illustrated in figure 3.3-3(a), is representative. Figures 3.3-3(a) through 3.3-4(b) illustrate the results of applying the filter in block position (065,001) to remove nonvegetation pixels; 933 pixels were removed as nonvegetation.

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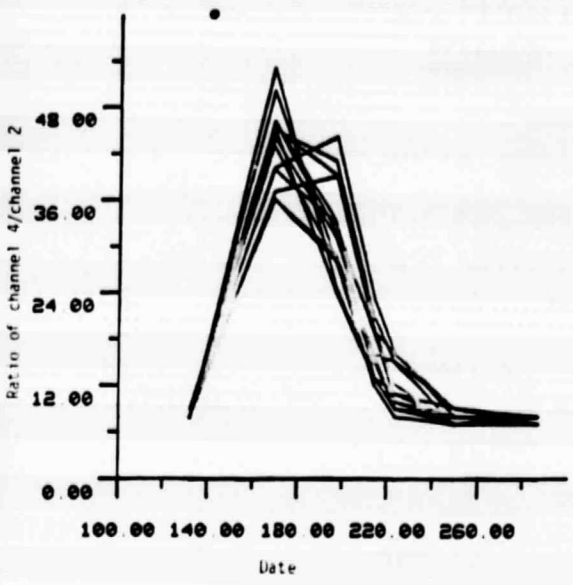
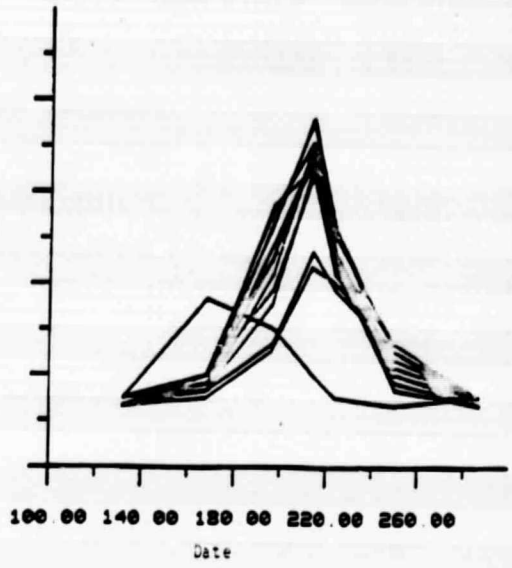
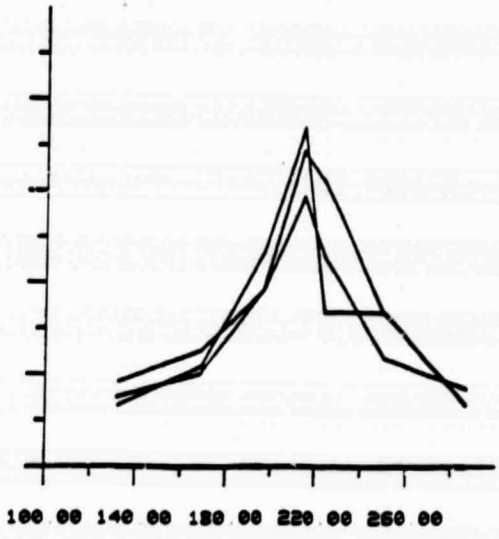


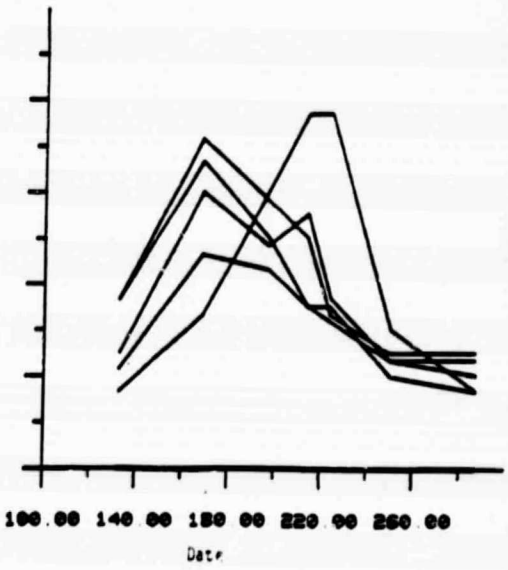
(a) Spring wheat.



(b) Sunflowers.



(c) Summer crops.



(d) Pasture.

Figure 3.3-1.- Major crop profiles of sample segment 185.

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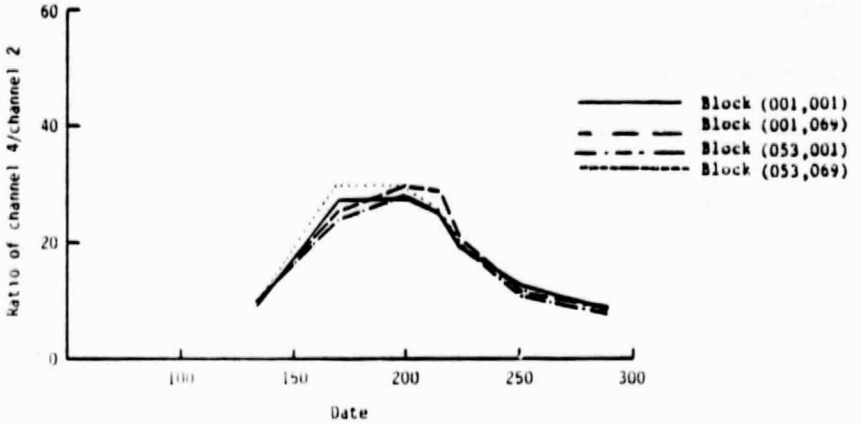
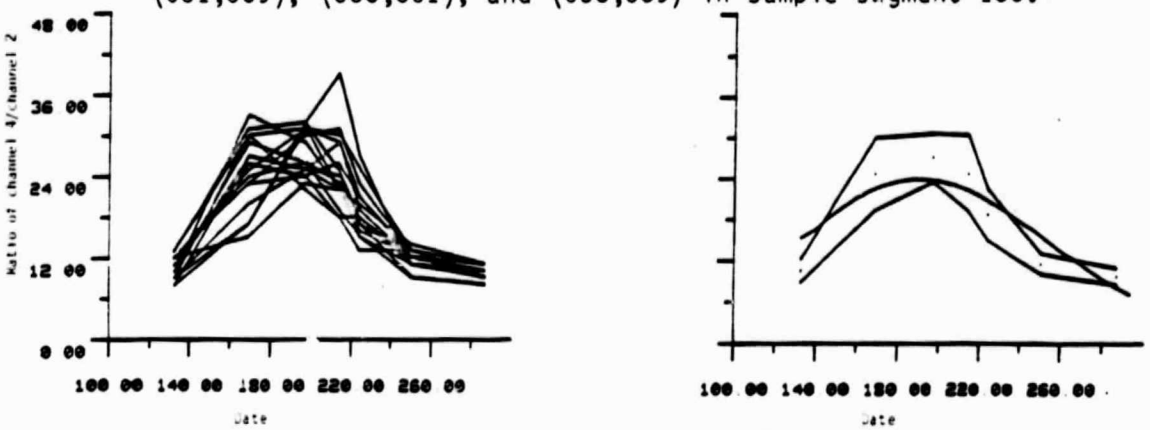
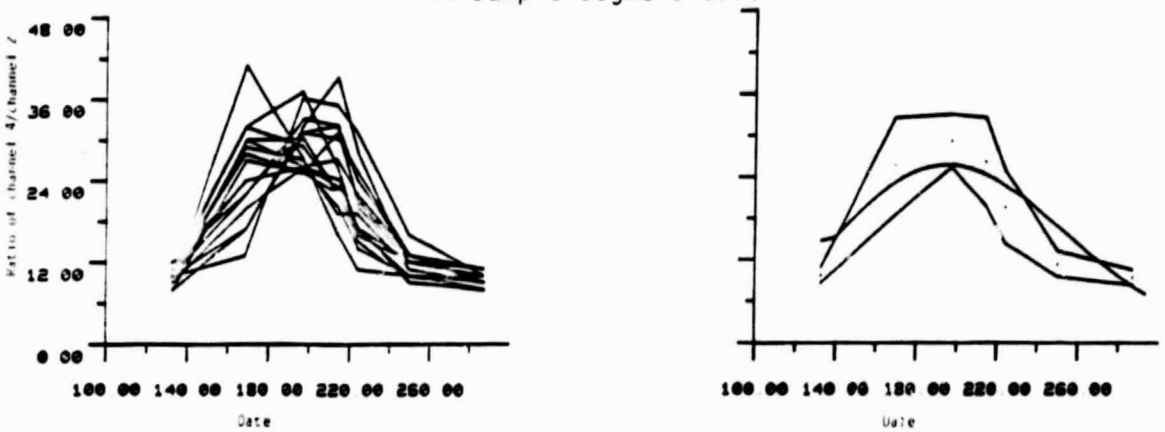


Figure 3.3-2.- Comparison of mean values of block positions (001,001), (001,069), (053,001), and (053,069) in sample segment 185.



(a) Data. (b) Approximating curve.

Figure 3.3-3.- All pixel input for block position (065,001) in sample segment 185.



(a) Data. (b) Approximating curve.

Figure 3.3-4.- Vegetation pixel input for block position (065,001) in sample segment 185.

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Figure 3.3-5 shows the ground truth for block position (001,001); S is spring wheat, V is sunflowers, X and C are corn and soybeans, respectively, and * is pasture.

Block position (001,001) was chosen for the LAC-scale simulation. This was a poor choice since much of the area lacks ground truth identification, but it was a good choice for sampling major crops. Figures 3.3-6(a) through (b) illustrate the 16 cells with major content for block position (001,001).

Summary

This segment had a variety of crops. Field size is moderate, so degradation of the signatures occurred at the LAC level. The cell profiles were not identifiable with the pure crop profiles. GAC-scale coverage was homogeneous over the area, although the data pattern is not able to be crop differentiated using either LAC or GAC, scene content could probably only be analyzed as "cropland."

3.4 SAMPLE SEGMENT 1602, MOUNTRAIL COUNTY, NORTH DAKOTA

Sample segment 1602, Mountrail County, North Dakota, had a scene content of 11 percent water, 11 percent pasture, 28 percent idle crop land, and 26 percent spring wheat. There were only four acquisitions available for this segment.

The acquisitions used were these:

Julian date	Landsat	Comments
78174	2	Spring grains emergent
78211	2	Scattered clouds; summer crops emergent, spring crops vigorous
78228	2	Grains senescent to ripe, some harvested
78264	2	Spring grains harvested

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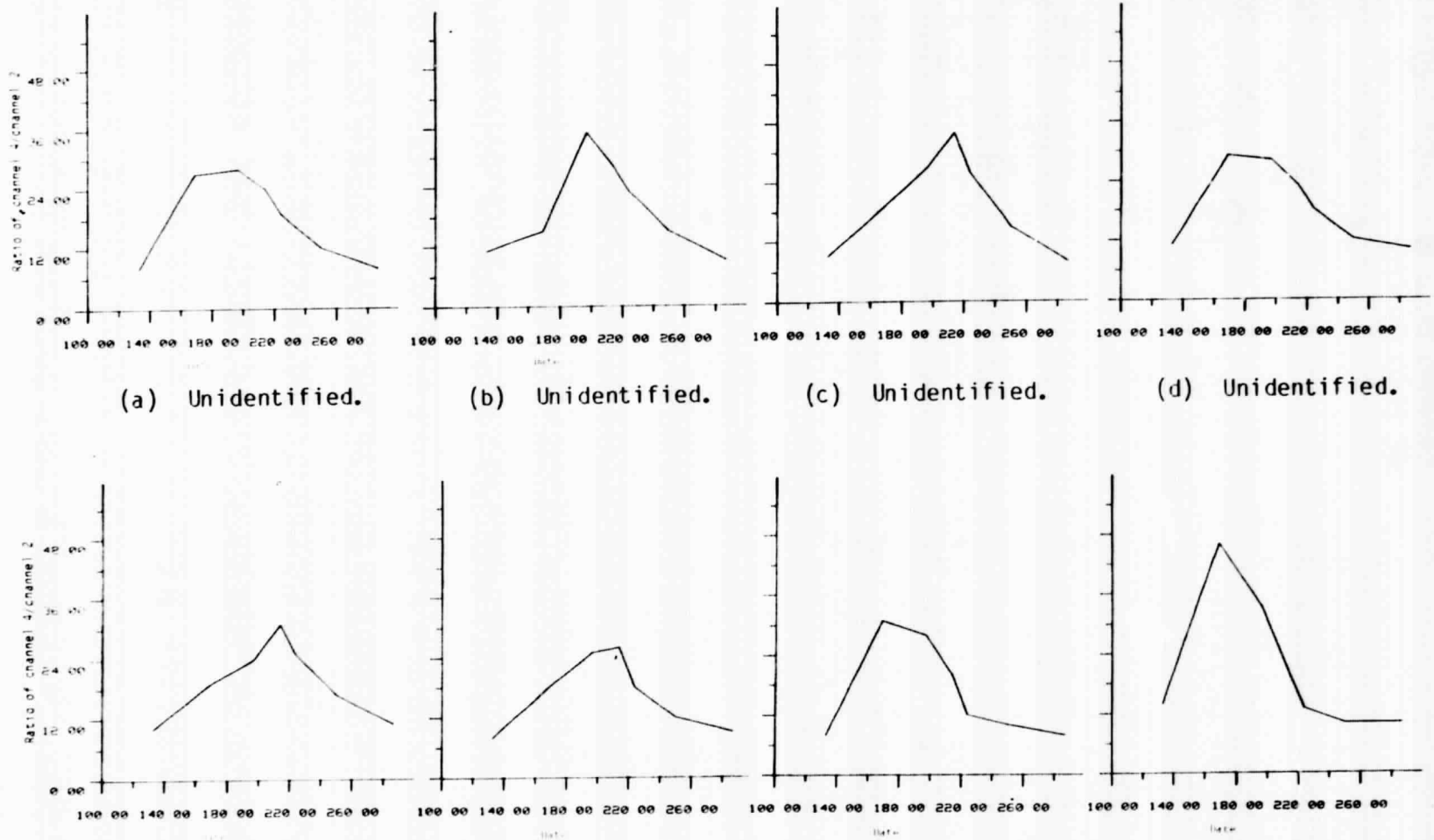
Figure 3.3-5.- The AA digitized ground truth map covering block position (001,001) in sample segment 185.



(a) Unidentified. (b) Unidentified. (c) Unidentified. (d) Unidentified.

(e) Unidentified. (f) Wheat, idle land, and sunflowers. (g) Spring wheat and corn. (h) Pasture and spring wheat.

Figure 3.3-6.- The data profiles of the 16 cells in block position (001,00') in sample segment 185.

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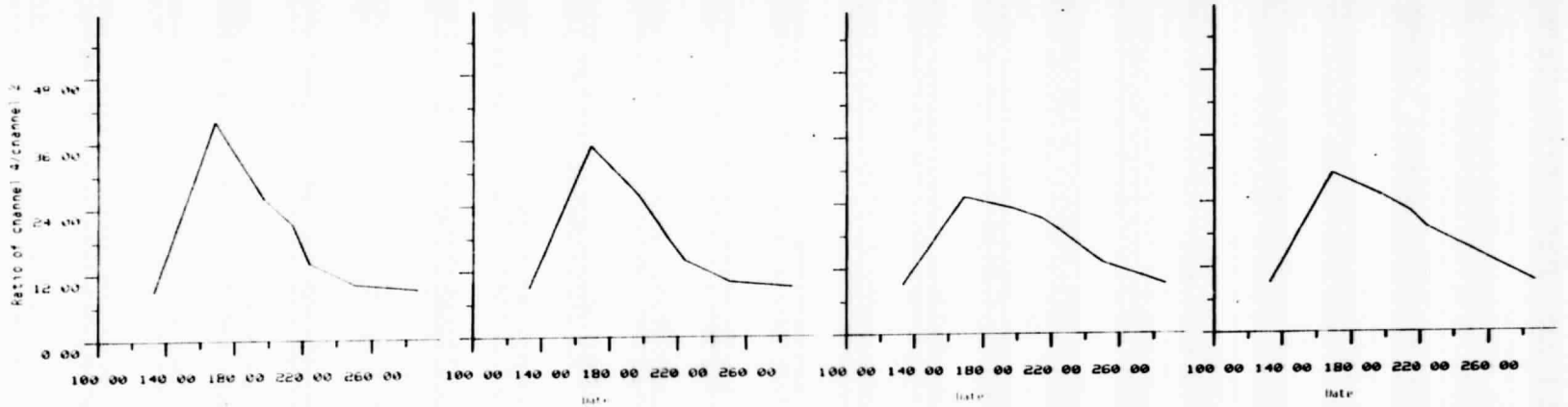
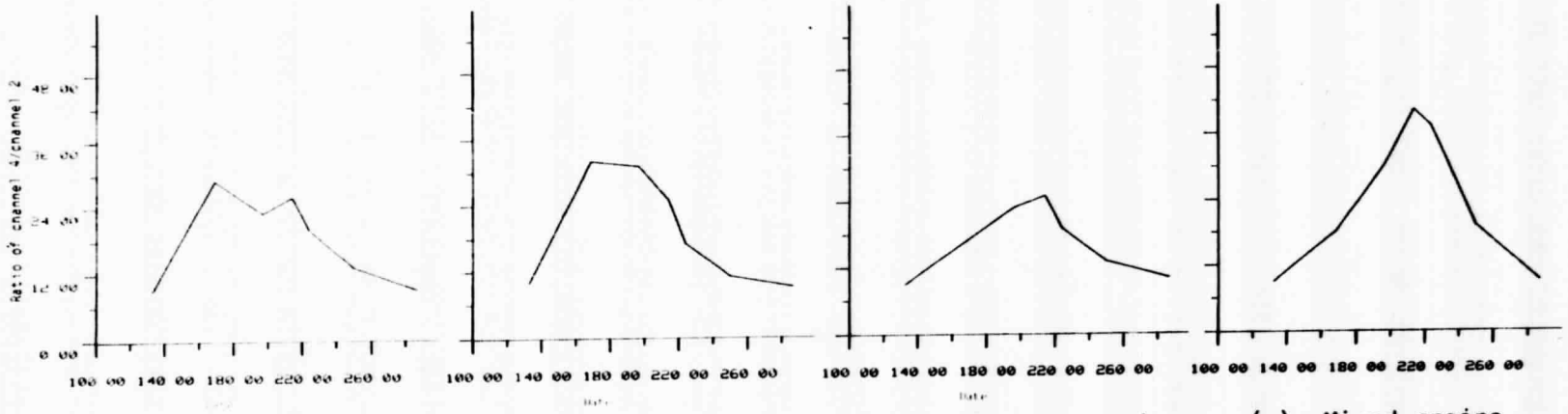


(i) Corn, soybeans, and spring wheat.

(j) Spring wheat and soybeans.

(k) Corn, soybeans, and spring wheat

(l) Spring wheat and sunflowers.



(m) Sunflowers and barley.

(n) Spring wheat and soybeans.

(o) Sunflowers, spring wheat, and corn.

(p) Mixed grains.

Figure 3.3-6.- Concluded.

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A large percentage of the upper half of this segment was water. Major scene components are illustrated in figures 3.4-1(a) through (c). Figure 3.4-1(c) appears to have two profiles; however, splitting this into spring wheat figure 3.4-2(a) and durum wheat figure 3.4-2(b) only defines a trend to separability. There are some strip field areas in this segment.

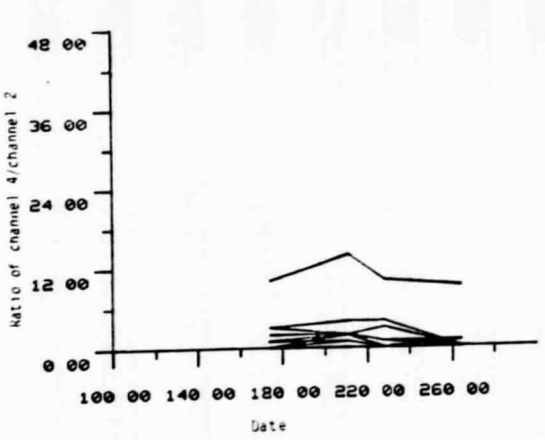
Below is a comparison of block profiles. The data did not describe a good curve, and in most plots the curve fitting the program failed. No block profile representative of the segment was able to be defined.

Block position	A	α	β	t_o
(001,001)	0.2	10.6	1.3	117 days
(001,069)	2.5	0.6	0.2	67 $\pm$ 76 days
(001,129)	2.8	0.9	0.2	73 days
(053,001)	Not applicable (N.A.)			
(053,069)	N.A.			
(053,129)	1.8	5.9	0.7	126 $\pm$ 1 day
(065,001)	N.A.			
(065,069)	3.3	0.0	0.2	0.0
(065,129)	1.6	8.7	1.0	133 days

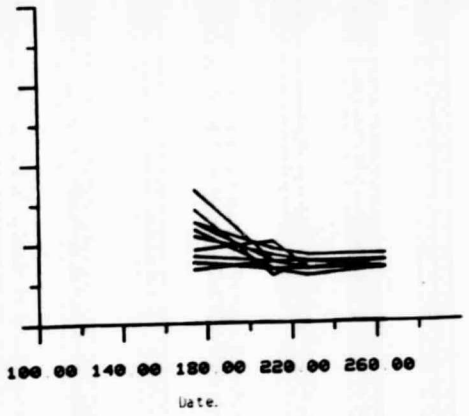
Figures 3.4-3(a) and (b) show the input for all pixels for block position (001,001), and figures 3.4-4(a) and (b) show the input for vegetation pixels for the same block position. Of the 3536 pixels input, 2026 were eliminated as nonvegetation. Vegetation only content converges toward the spring wheat-durum wheat signature that is illustrated in figure 3.4-2.

Since the GAC could not be approximated by a curve, it was compared numerically; data graphs for block positions (001,069), (001,129), (053,001), (053,069), (053,129), (065,001), (065,069), and (065,129) are illustrated in figures 3.4-5(a) through (h).

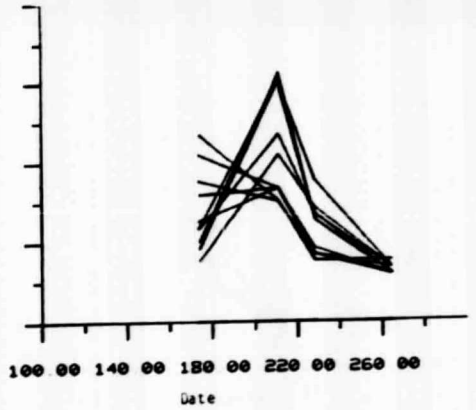
Figure 3.4-6 is a graph of the data mean values in block positions (001,001), (001,069), (053,001), and (053,069).



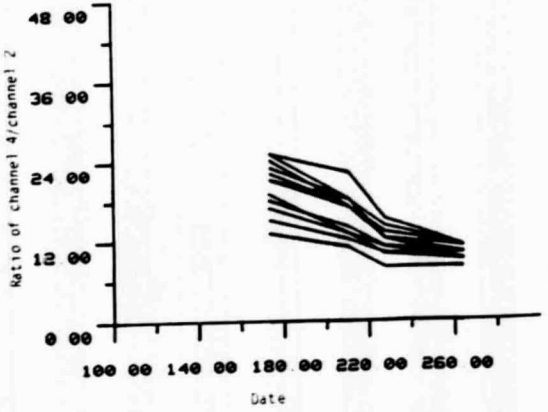
(a) Water.



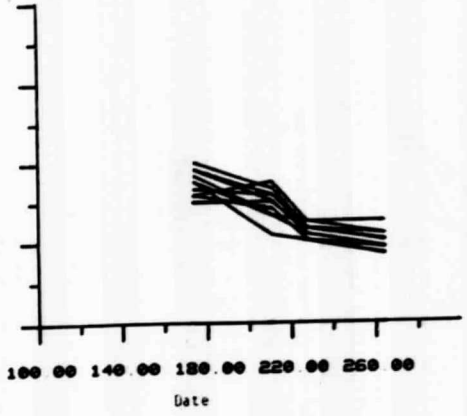
(b) Idle cropland.



(c) Spring wheat.



(d) Grass.



(e) Pasture.

Figure 3.4-1.- Major crop profiles of sample segment 1602.

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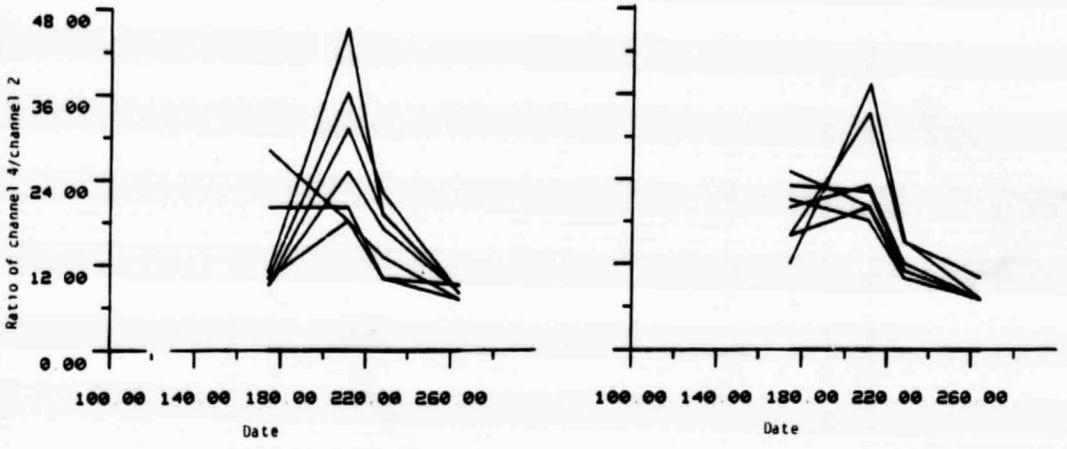
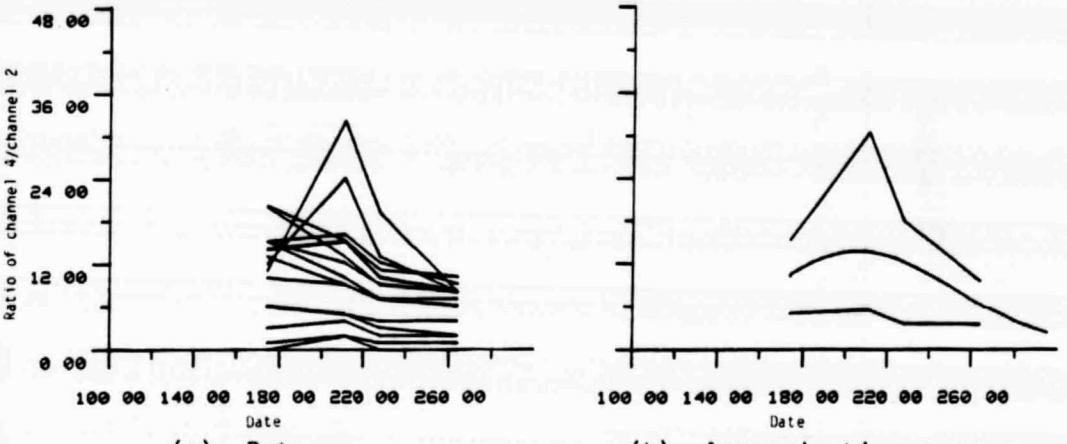


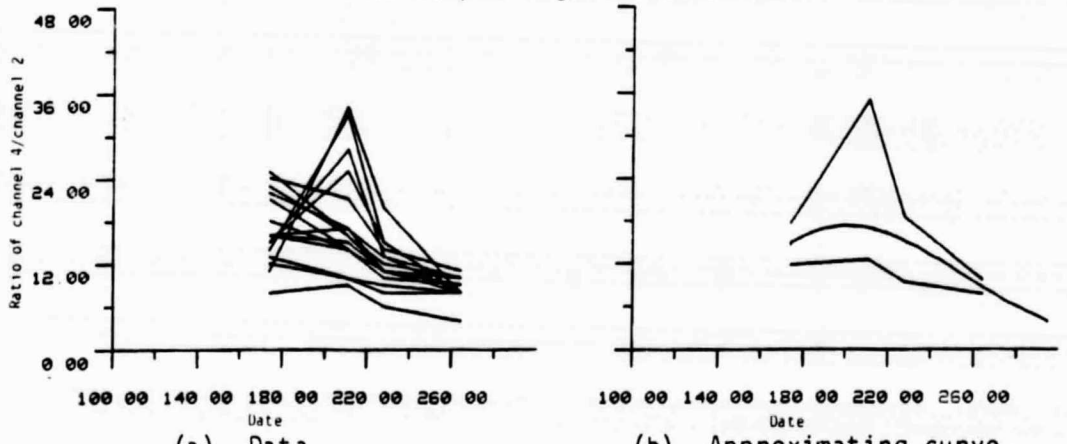
(a) Spring wheat. (b) Durum wheat.

Figure 3.4-2.- Spring wheat and durum wheat in sample segment 1602.



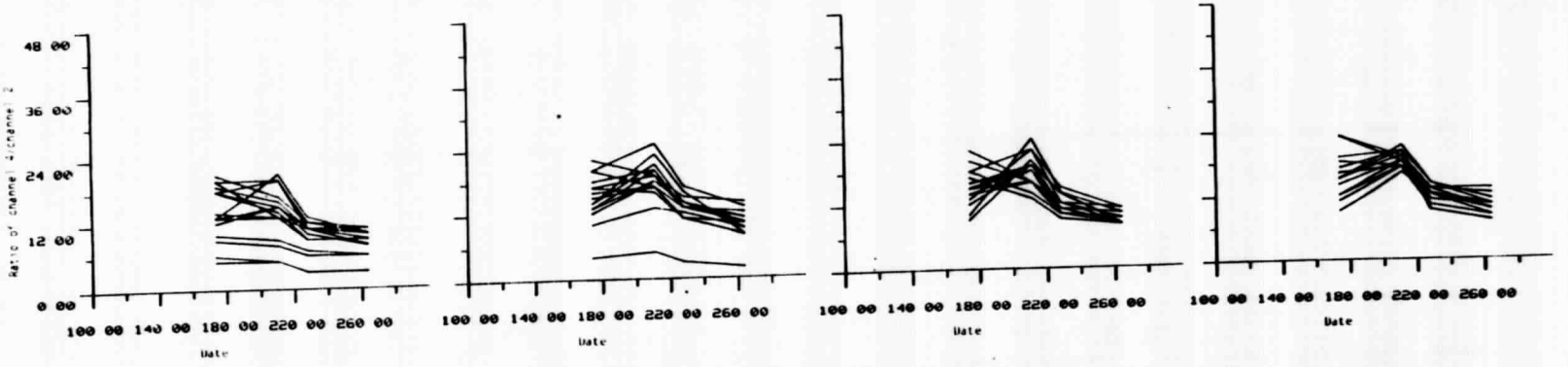
(a) Data. (b) Approximating curve.

Figure 3.4-3.- All pixel input for block position (001,001) in sample segment 1602.



(a) Data. (b) Approximating curve.

Figure 3.4-4.- Vegetation pixel input for block position (001,001) in sample segment 1602.

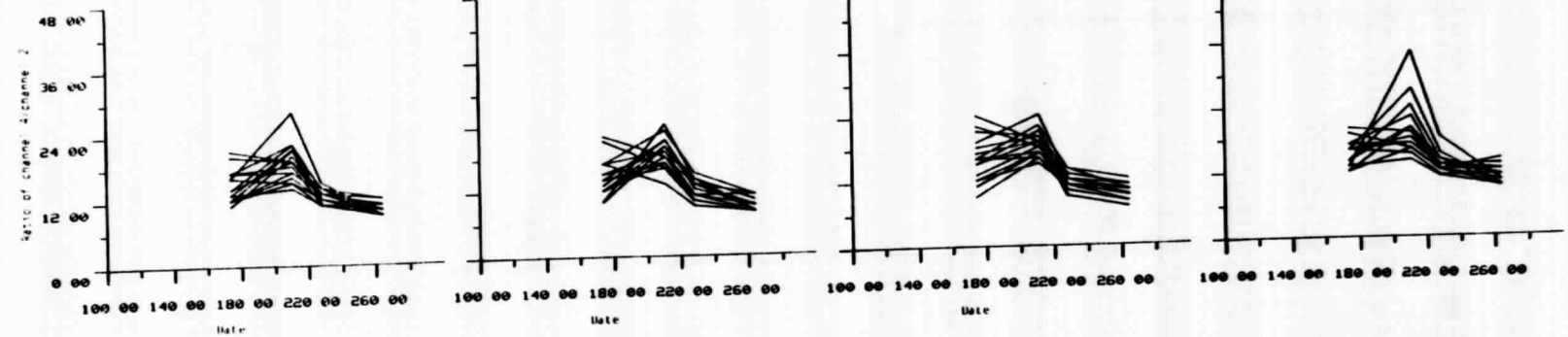


(a) Block position (001,069).

(b) Block position (001,129).

(c) Block position (053,001).

(d) Block position (053,069).



(e) Block position (053,129).

(f) Block position (065,001).

(g) Block position (065,069).

(h) Block position (065,129).

Figure 3.4-5.- GAC coverage for block positions (001,069), (001,129), (053,001), (053,069), (053,129), (065,001), (065,069), and (065,129).

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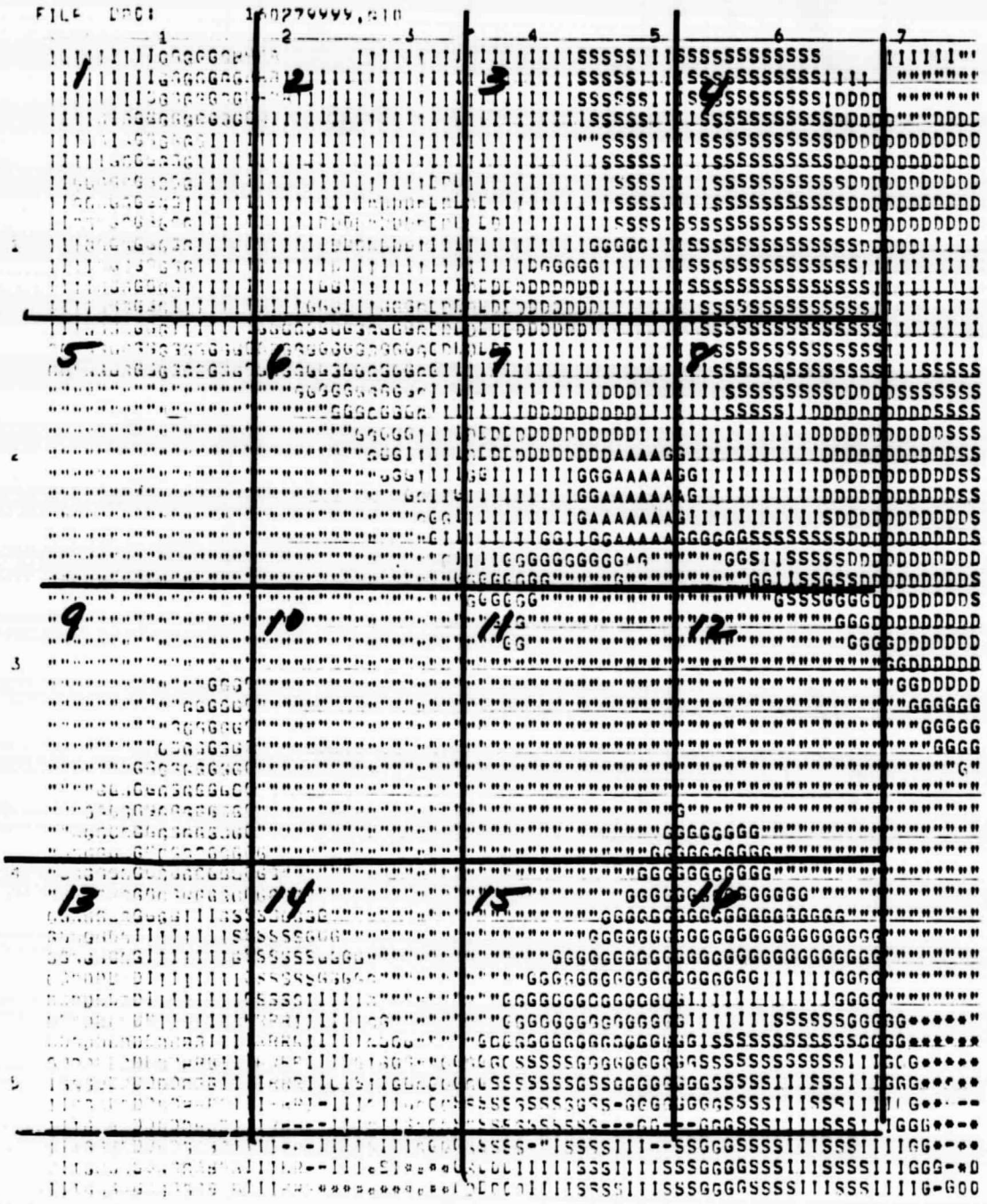

Figure 3.4-6.- Comparison of mean values of block positions (001,001), (001,069), (053,001), and (053,069) in sample segment 1602.

Figure 3.4-7 illustrates the digitized ground truth for block position as (001,001). In this map, G is grass, " is water, D and S are spring wheat, and I is idle land.

Figures 3.4-8(a) through (p) illustrate the data profiles of the 16 cells (with major cell content) in block position (001,001).

Summary

This segment was interesting because it contains a large amount of water. However, processing problems precluded use of the curve approximation of data; the data simply did not describe a curve for most of the LAC or the GAC cells. Of the segment components, grass and water did not fit the curve definition over the available acquisitions; spring wheat and durum wheat did allow curve approximations. Cells of LAC scale were identifiable with the crop profiles, however, the signatures degraded at the GAC scale level.

3.5 SAMPLE SEGMENT 1653, BURLEIGH COUNTY, NORTH DAKOTA

Sample segment 1653, Burleigh County, North Dakota, is a strip field area that had a scene content of 15 percent spring wheat, 12 percent grass, and 37 percent pasture. A river ran through the scene, and a lake was in the lower right quadrant. There were no pure cells (LAC level) of spring wheat, although pasture, grass, and water are sampled in almost pure form.

Acquisition coverage over the growing season was short, but it is probably adequate because the area contains spring vegetation.

Julian date	Landsat	Comments
78119	2	Grass, pasture emergent; spring wheat fields plowed
78136	2	
78154	2	Spring wheat emergent
78155	2	

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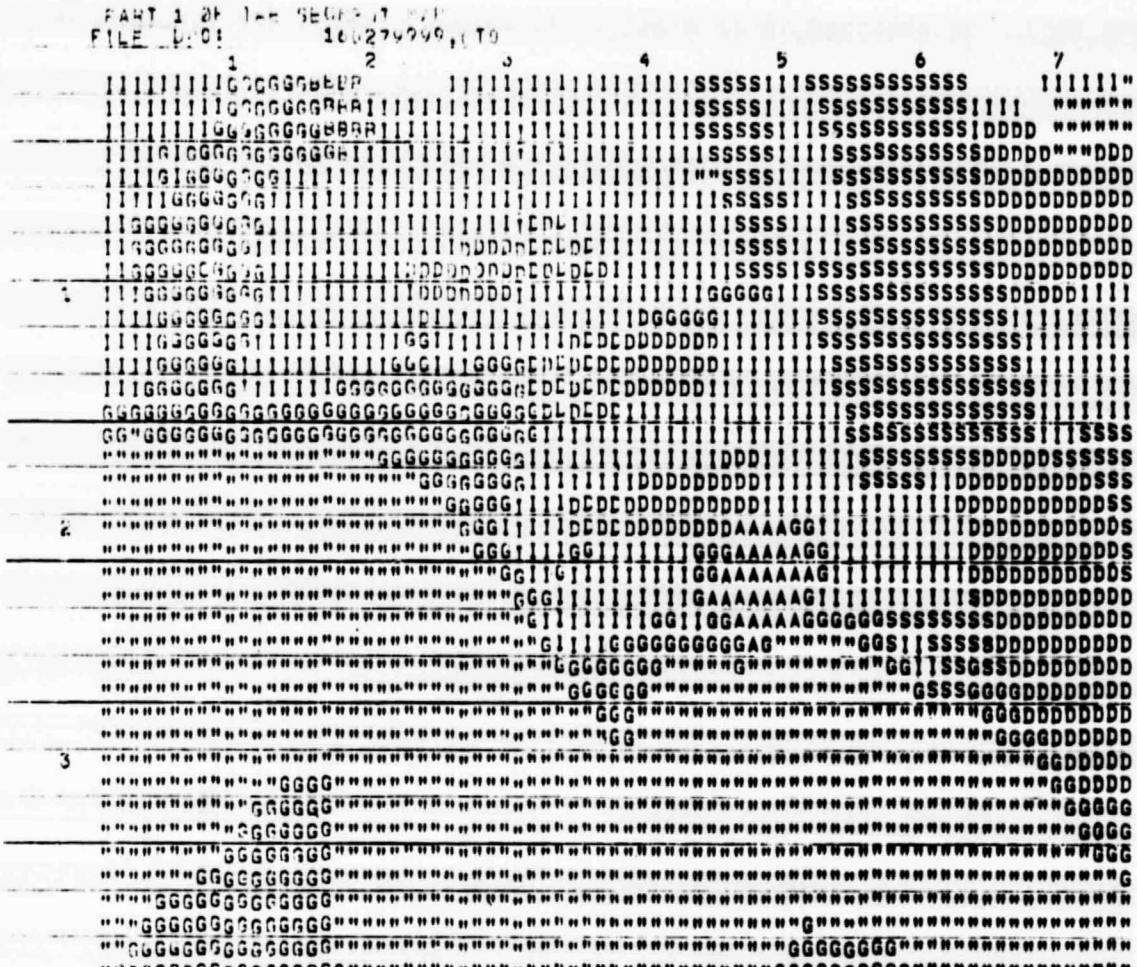
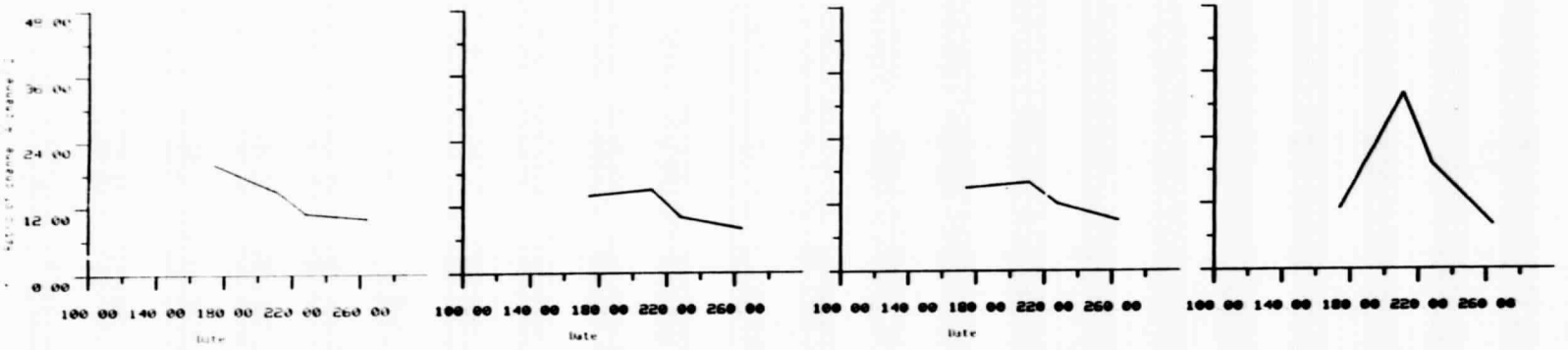
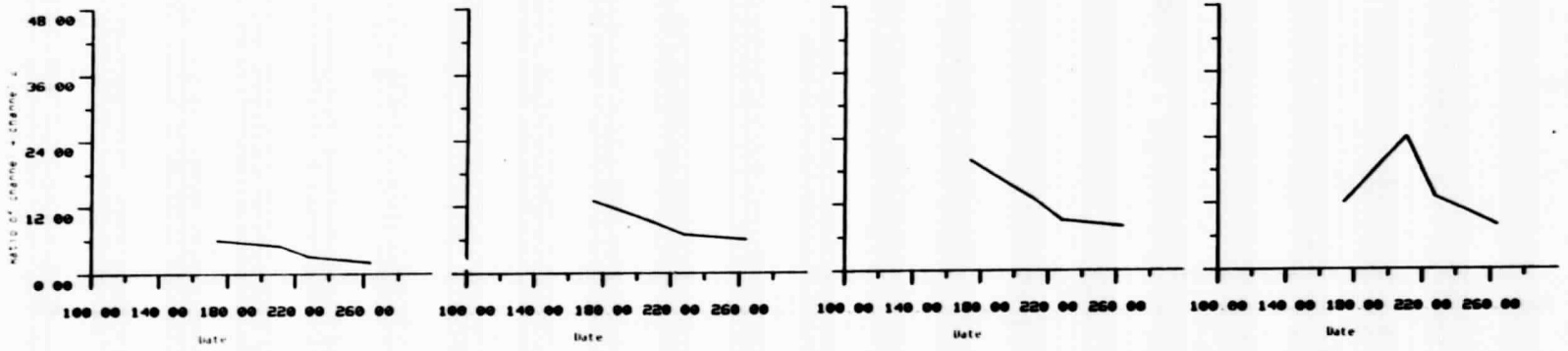


Figure 3.4-7.- The AA digitized ground truth map covering block position (001,001) in sample segment 1602.



(a) Grass and idle land. (b) Idle land and wheat. (c) Idle land and spring wheat. (d) Spring wheat.



(e) Water. (f) Water and grass. (g) Spring wheat and idle land. (h) Spring wheat and idle land.

Figure 3.4-8.- The data profiles of the 16 cells in block position (001,001) in sample segment 1602.

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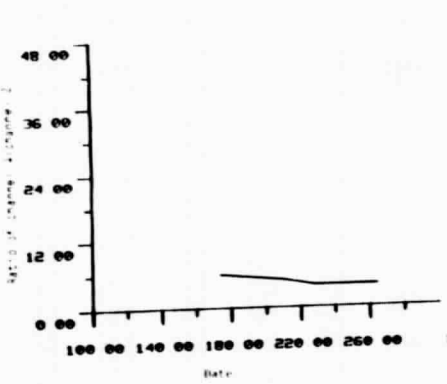
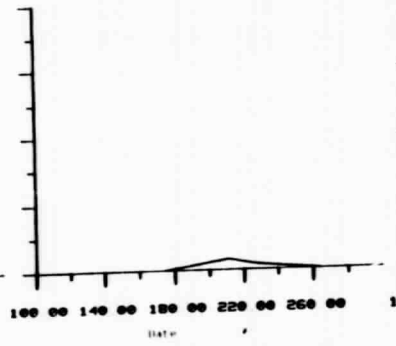
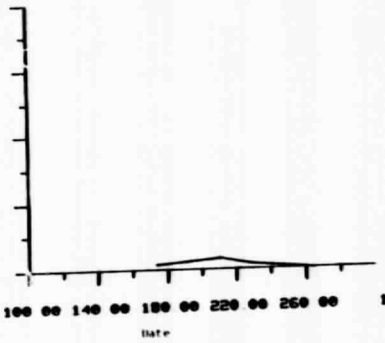


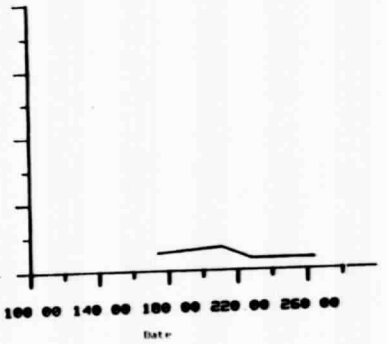
(i) Water and grass.



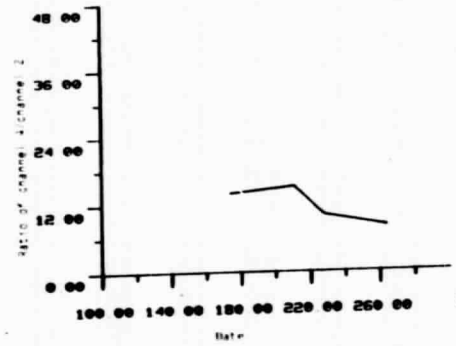
(j) Water.



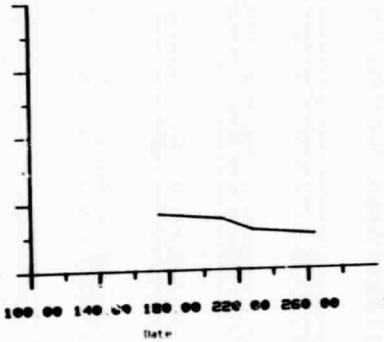
(k) Water.



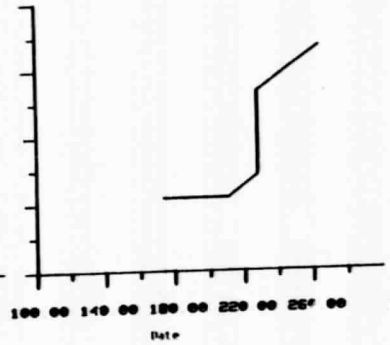
(l) Water.



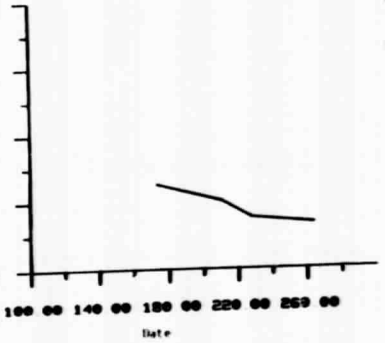
(m) Grass, spring wheat, and idle land.



(n) Water and grass.



(o) Grass and water.



(p) Grass, idle land, and water.

Figure 3.4-8.- Concluded.

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Julian date	Landsat	Comments
78191	2	Small scattered clouds
78209	2	Spring wheat ripe
78217	3	

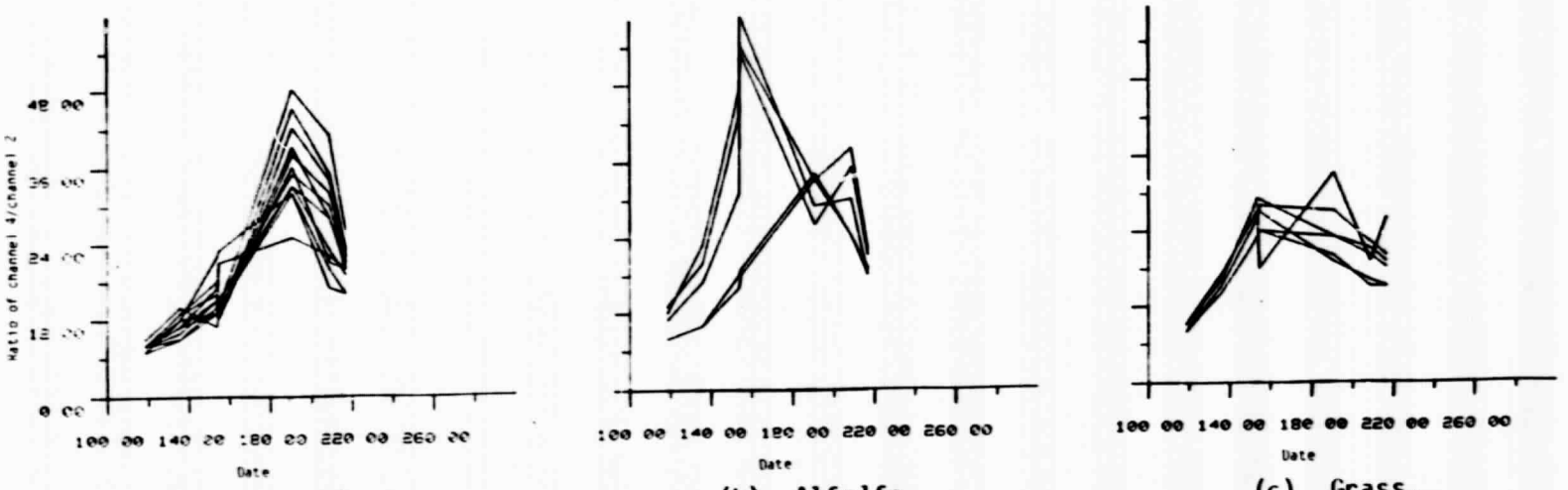
Major scene component profiles are illustrated in figures 3.5-1(a) through (e); figure (a) is spring wheat, figure (b) is alfalfa, figure (c) is grass, figure (d) is pasture, and figure (e) is water.

The following chart compares the block profiles for this segment taken from the curve fitted to seven acquisitions.

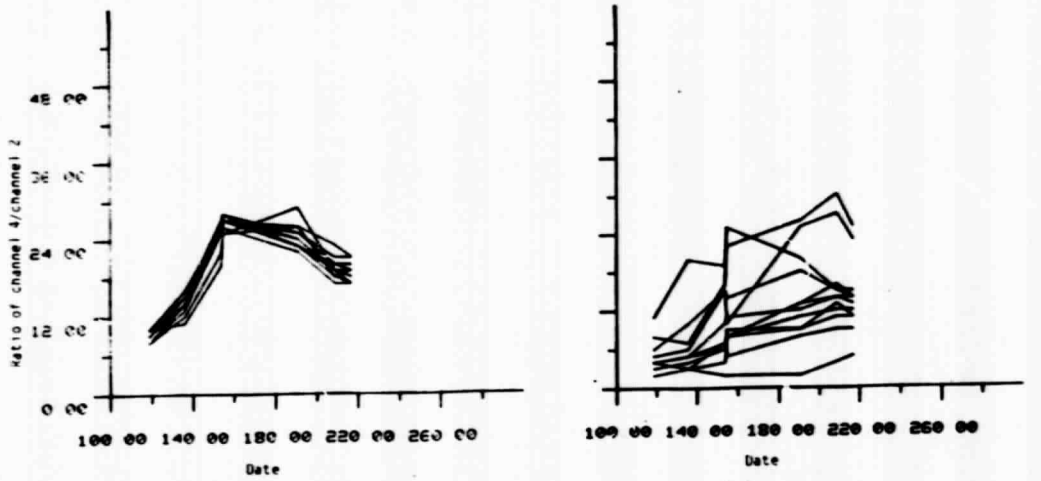
Block position	A	α	β	t_o
*(001,001)	2.1	8.7	1.4	117
*(001,069)	2.1	8.4	1.3	117
(001,129)	1.9	10.9	1.7	121
*(053,001)	2.1	10.4	1.7	117
*(053,069)	2.1	9.1	1.4	117
(053,129)	2.1	8.4	1.3	118
(065, 001)	2.1	10.0	1.6	116
(065, 069)	2.1	9.2	1.5	117
(065, 129)	2.0	9.4	1.5	120

The data tracks appeared more homogeneous and similar than the constant values above would indicate. Most of the blocks had a good grass or pasture signature. Figure 3.5-2 is a graph of the mean values of the data marked by asterisks in the preceding chart.

Block position (065,129) was selected for application of the nonvegetation filter because this block position contained appreciable water and nonagriculture; 1473 pixels were removed as nonvegetation from the 3536 possible pixel input. The water signature was removed by the filter, leaving recognizable



(a) Spring wheat. (b) Alfalfa. (c) Grass.



(d) Pasture. (e) Water.

Figure 3.5-1.- Major crop profiles of sample segment 1653.

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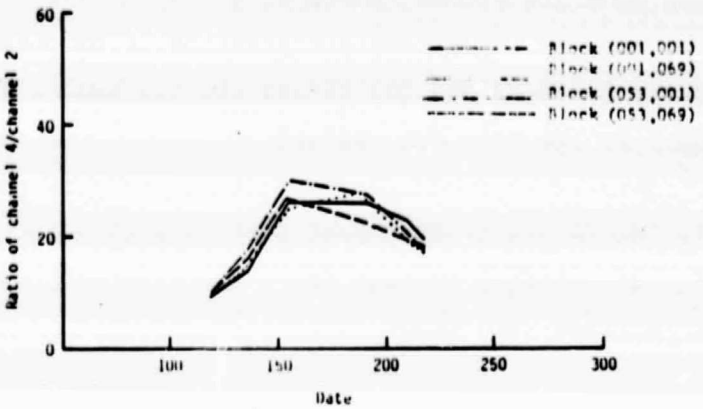
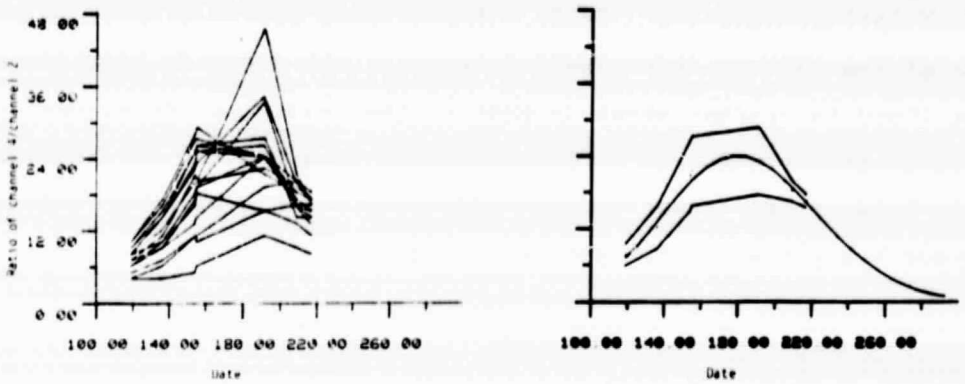
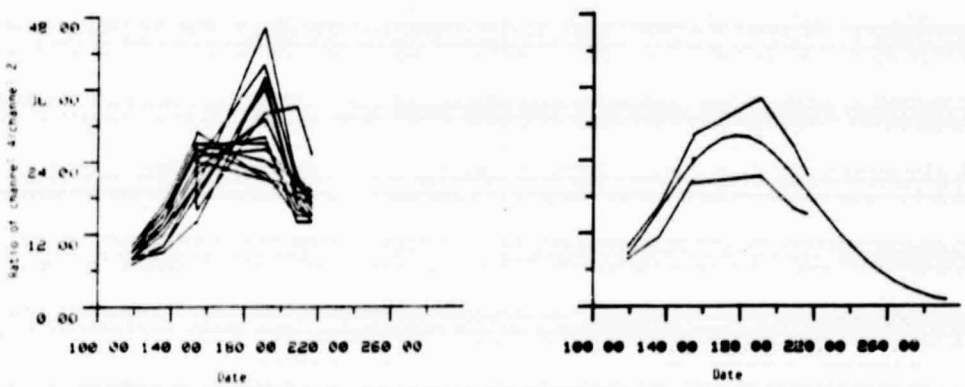


Figure 3.5-2.- Comparison of mean values of block positions (001,001), (001,069), (053,001), and (053,069) in sample segment 1653.



(a) Data. (b) Approximating curve.

Figure 3.5-3.- All pixel input for block position (065,129) in sample segment 1653.



(a) Data. (b) Approximating curve.

Figure 3.5-4.- Vegetation pixel input for block position (065,129) in sample segment 1653.

(compared to the pure signatures) pasture, grass, spring wheat, and alfalfa. Figures 3.5-3(a) and (b) illustrate all pixel input for block position (065,129); figures 3.5-4(a) and (b) illustrate the same area with vegetation pixels only input to the cell mean values.

Figure 3.5-5 is the AA digitized ground truth map covering a block in position (001,001). Figures 3.5-6(a) through (p) illustrates the data profiles of the cells in block position (001,001).

Summary

This segment was predominately pasture and grass, which have similar signatures, and spring wheat and alfalfa. Appreciable degradation of signature occurred at the LAC signature level because of the cropping practice of stripping the field for spring wheat in most of the segment. Occassionally, a pure signature of spring wheat or alfalfa appeared in a part of the segment where fields were larger for these crops. GAC-scale signatures were consistent over the segment and close to the pasture signature.

3.6 SAMPLE SEGMENT 222, DAWSON COUNTY, NEBRASKA

Sample segment 222, Dawson County, Nebraska, had a scene content of 88 percent corn and alfalfa (39 percent alfalfa and 49 percent corn). Field size was good, but a merged signature, LAC or GAC, with crops of such different spectral signatures would be hybrid and unrepresentative of either. The curve fit profile would tend to be unrepresentative because of large standard deviations as well as the different entries to the average.

Acquisition coverage was good; the following acquisitions were merged with ground truth.

Julian date	Landsat	Comments
78135	2	Alfalfa vigorous in some areas
78198	3	Corn vigorous; some alfalfa fields cut
78206	2	
78224	2	

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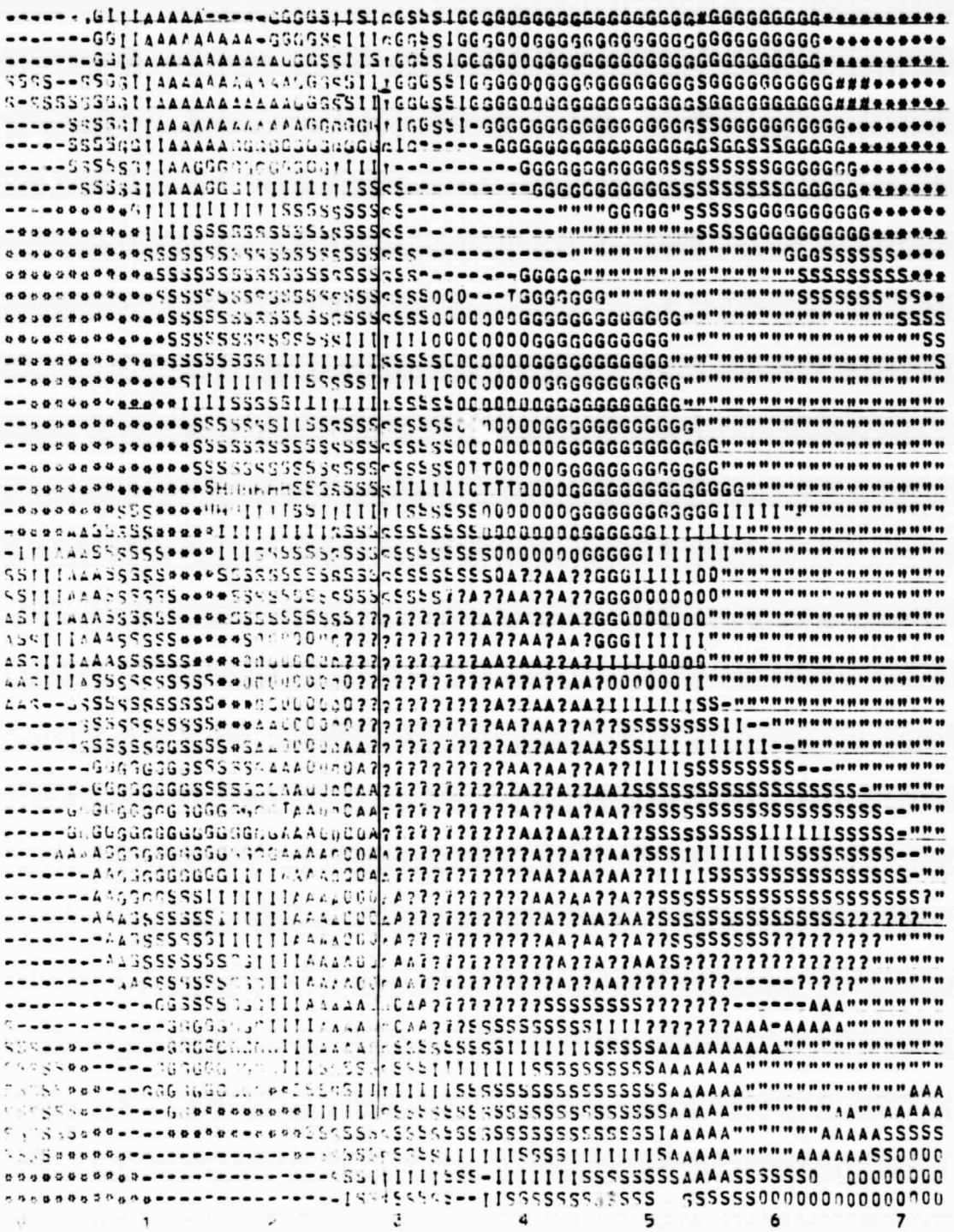
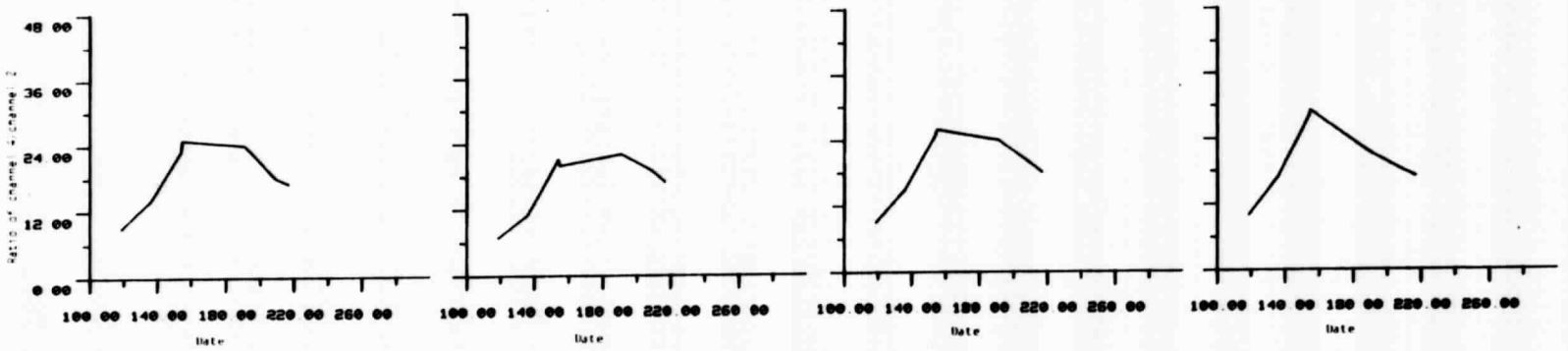


Figure 3.5-5.- The AA digitized ground truth map covering block position (001,001) in sample segment 1653.

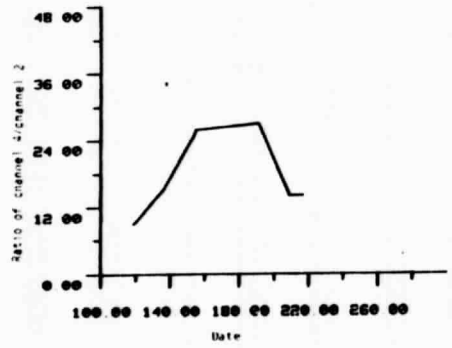


(a) Pasture.

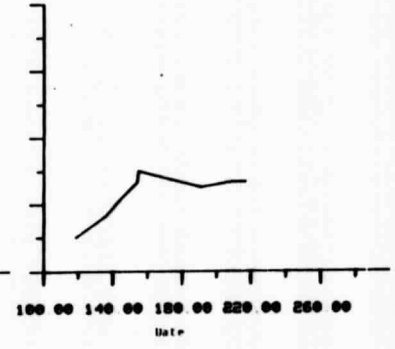
(b) Pasture, flax, and idle land.

(c) Grass and idle land.

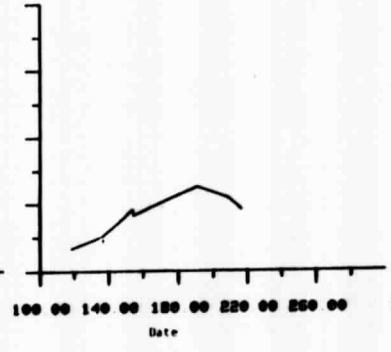
(d) Pasture.



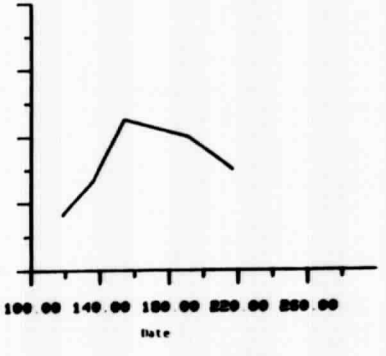
(e) Spring wheat and pasture.



(f) Pasture and spring wheat.



(g) Pasture and idle land.



(h) Spring wheat and stripped fields.

Figure 3.5-6.- The data profiles of the 16 cells in block position (001,001) in sample segment 1653.

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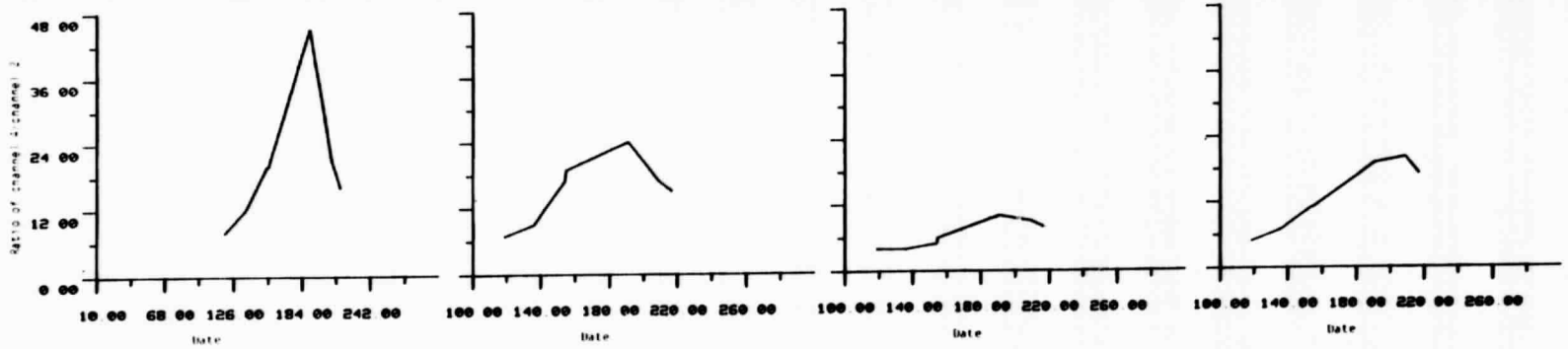
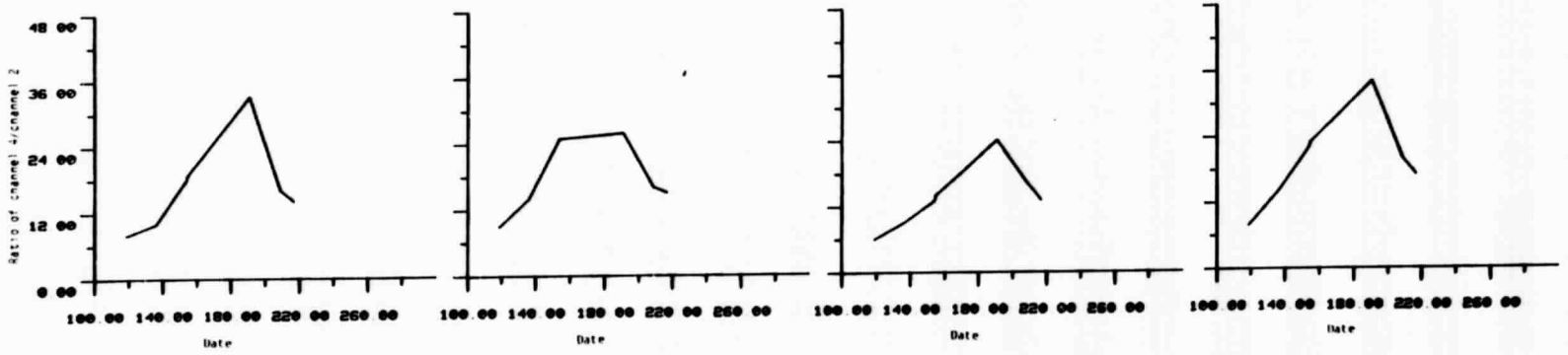


(i) Grass and spring wheat.

(j) Water, alfalfa, and pasture.

(k) Mixed grains.

(l) Spring wheat and idle land



(m) Pasture.

(n) Pasture and grass.

(o) Stream growth.

(p) Stream growth and grass.

Figure 3.5-6.- Concluded.

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Julian date	Landsat	Comments
78234	3	Corn senescent
78252	3	
78278	2	Corn in harvest, some alfalfa cut

Major crop profiles, corn and alfalfa, are illustrated in figures 3.6-1(a) and (b).

Below is a comparison of block profiles. Block position (001,001) was representative of most of the blocks; blocks positioned at (052,001) and 065,001) had more alfalfa which altered the block signatures.

Block position	A	α	β	t_o
(001,001)	2.1	7.5	0.8	1.2
(001,069)	2.1	7.5	0.9	1.2
(001,129)	2.1	7.4	0.8	1.2
(053,001)	2.3	4.8	0.5	1.2
(053,069)	2.2	6.7	0.8	1.2
(053,129)	2.3	6.1	0.7	1.2
(065,001)	2.4	4.6	0.5	1.2
(065,069)	2.2	6.9	0.8	1.2
(065,129)	2.3	6.2	0.7	1.2

This segment was so highly vegetated that there really was no area of nonvegetation in the segment. Applying the vegetative filter to input for block position (001,001) eliminated only 283 pixels [figs. 3.6-2(a) and (b) and 3.6-3(a) and (b)].

Figure 3.6-4 is a composite of the graphs of the mean data values of the blocks positioned at (001,001), (001,069), (053,001), and (053,069).

LAC simulation was done in block position (001,001). Figure 3.6-5 illustrates the digitized ground truth for this area. Figures 3.6-6(a) through (p) presents the data profiles of the 16 cells with major cell content.

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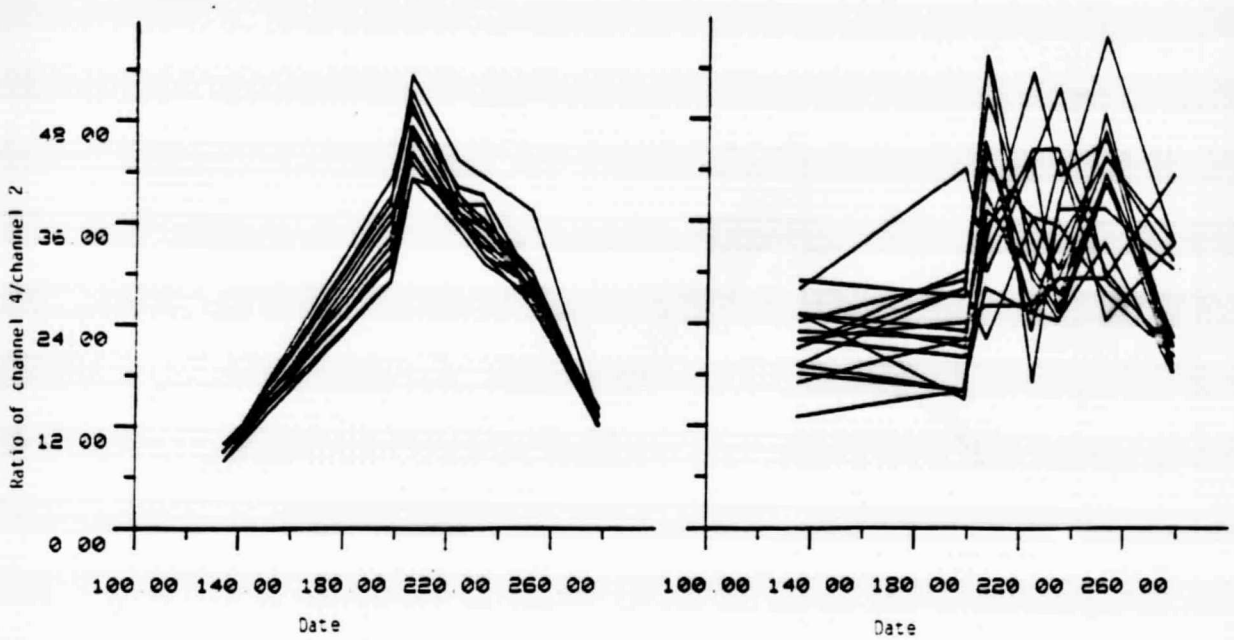
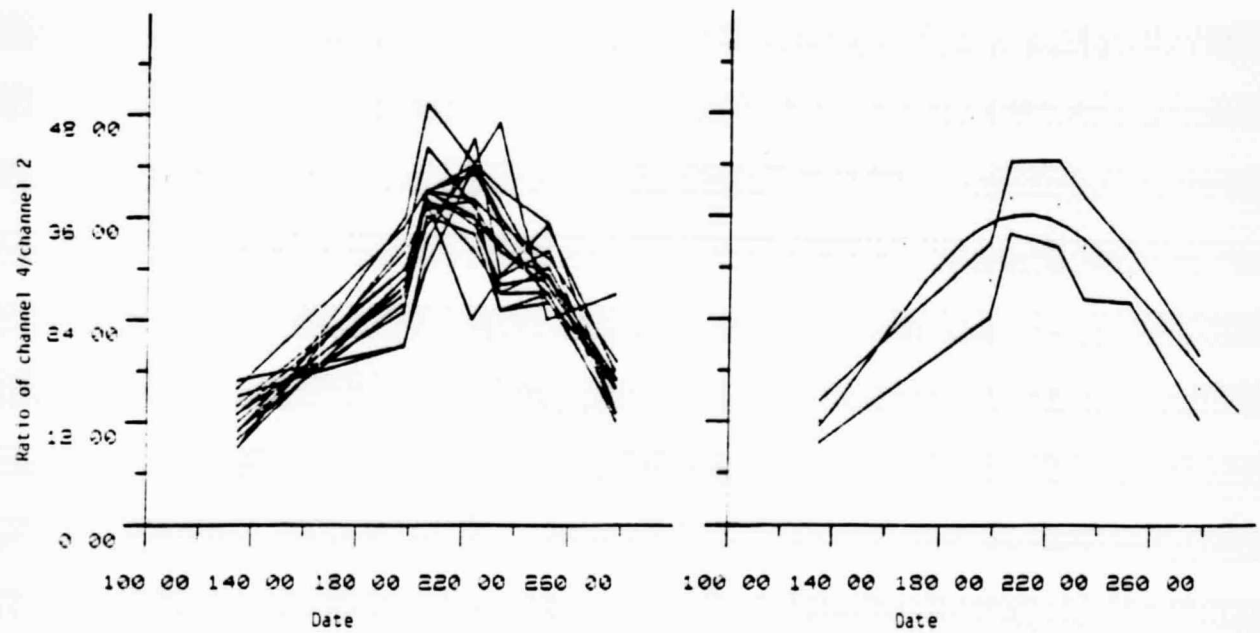


(a) Corn. (b) Alfalfa.

Figure 3.6-1.- Major scene components of sample segment 222.



(c) Data. (b) Approximating curve.

Figure 3.6-2.- All pixel input for block position (065,129) in sample segment 222.

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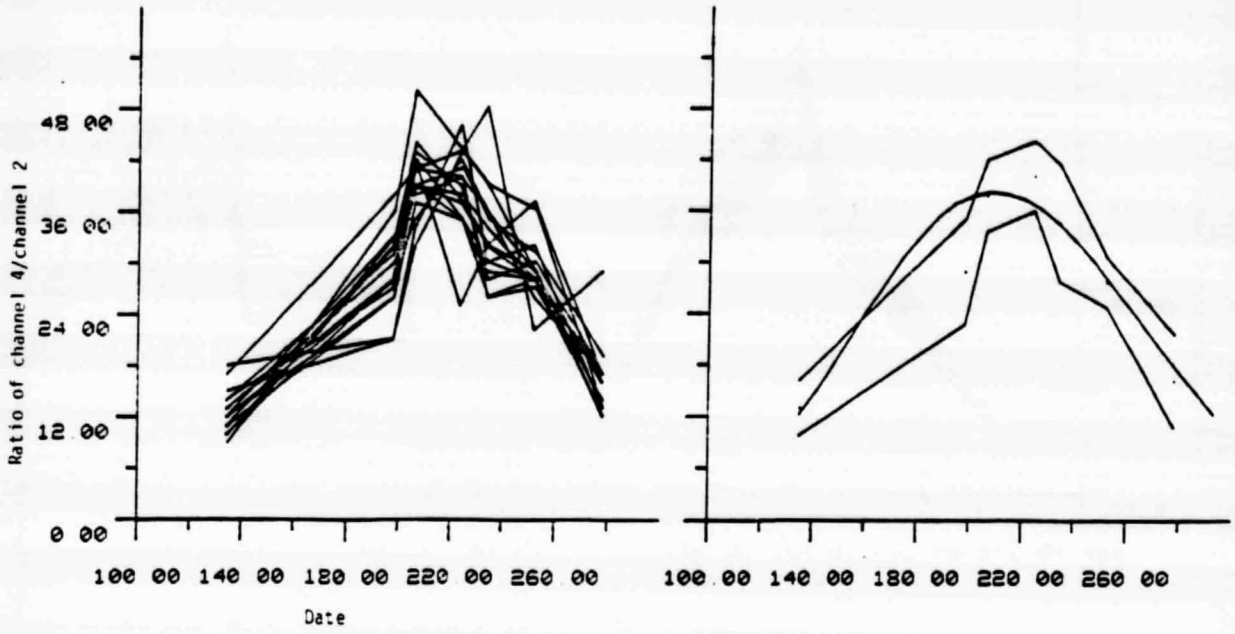

(a) Data. (b) Approximating curve.

Figure 3.6-3.- Vegetation pixel input for block position (065,129) in sample segment 222.

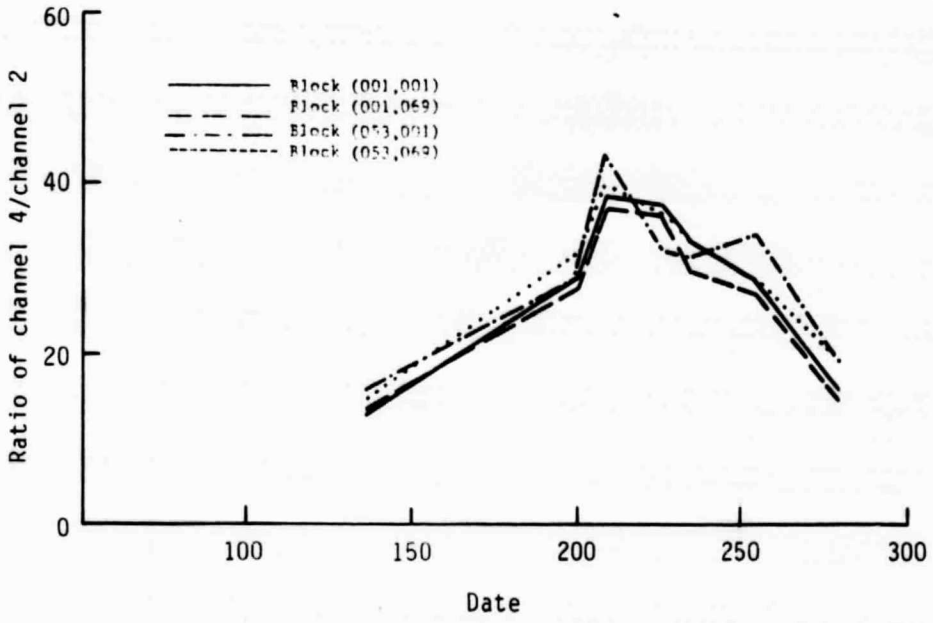

Figure 3.6-4.- Comparison of mean values of block positions (001,001) (001,069), (053,001), and (053,069) in sample segment 222.

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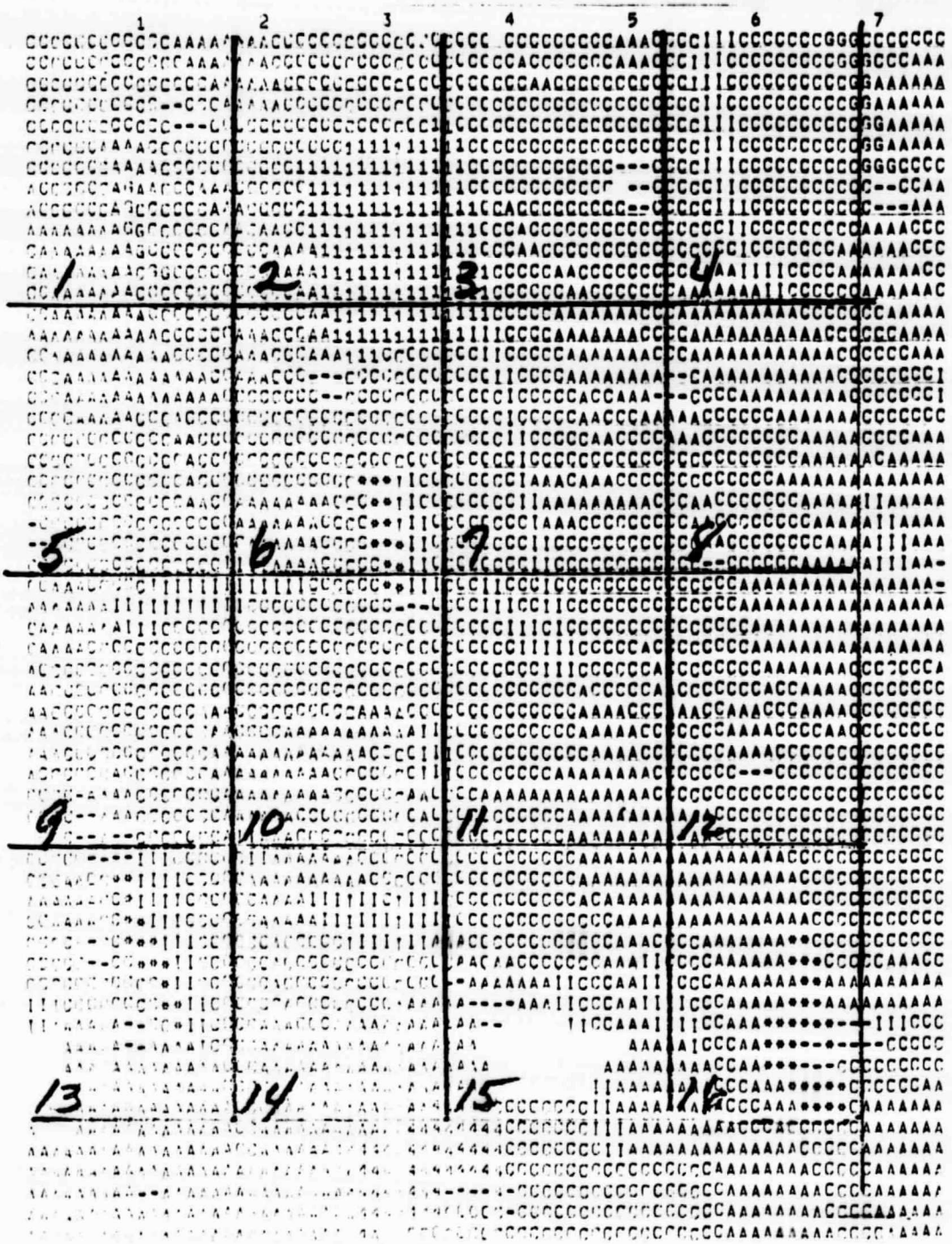
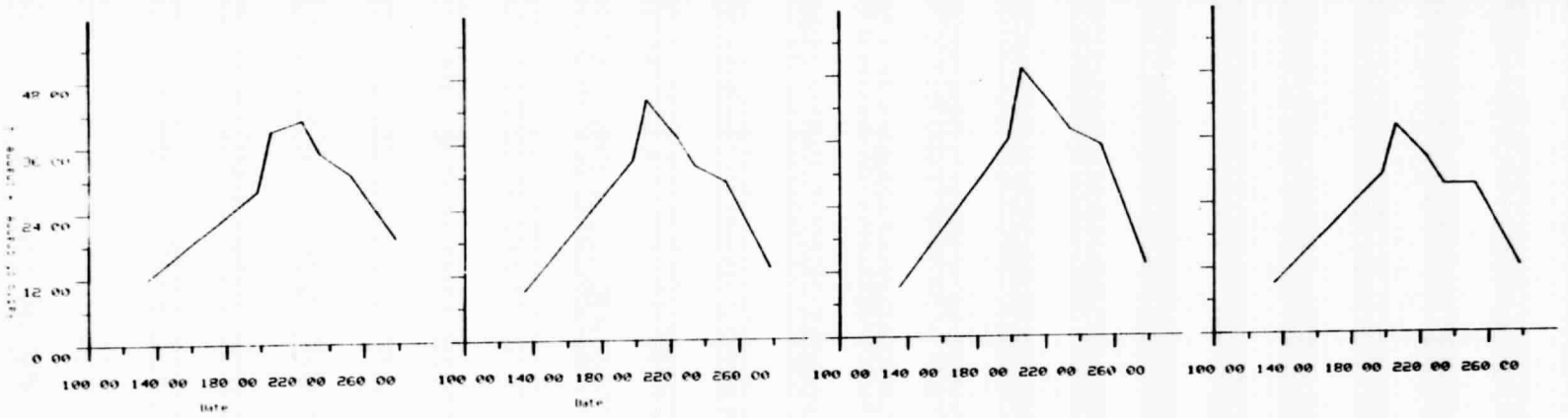


Figure 3.6-5.- The AA digitized ground truth map covering block position (001,001) in sample segment 222.

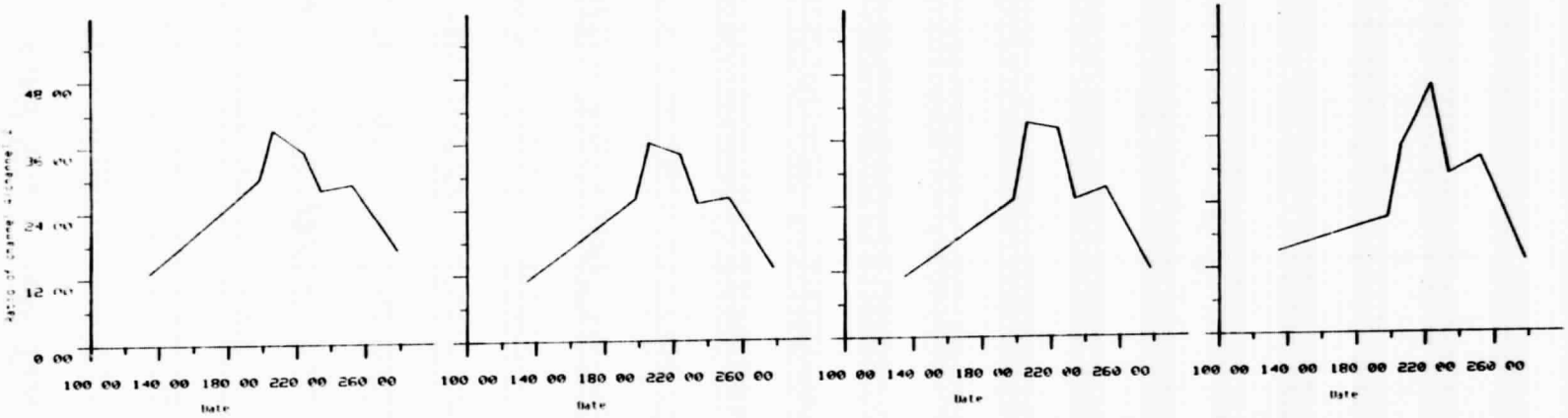


(a) Corn and alfalfa.

(b) Corn and alfalfa.

(c) Corn.

(d) Corn.



(e) Corn and soybeans missing.

(f) Soybeans and corn.

(g) Soybeans and corn.

(h) Corn and soybeans.

Figure 3.6-6.- The data profiles of the 16 cells in block position (001,001) in sample segment 222.

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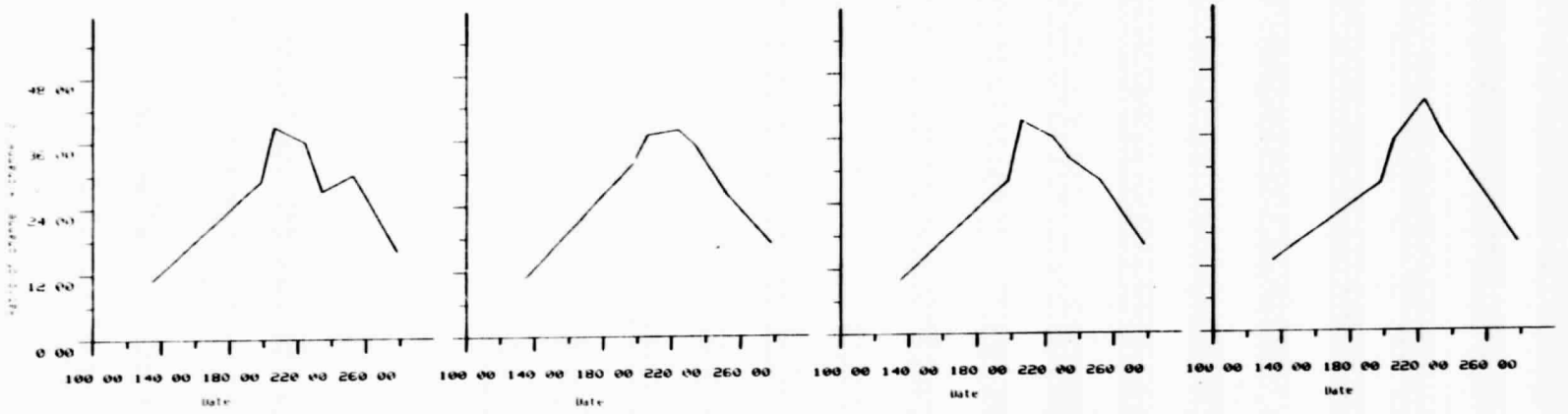
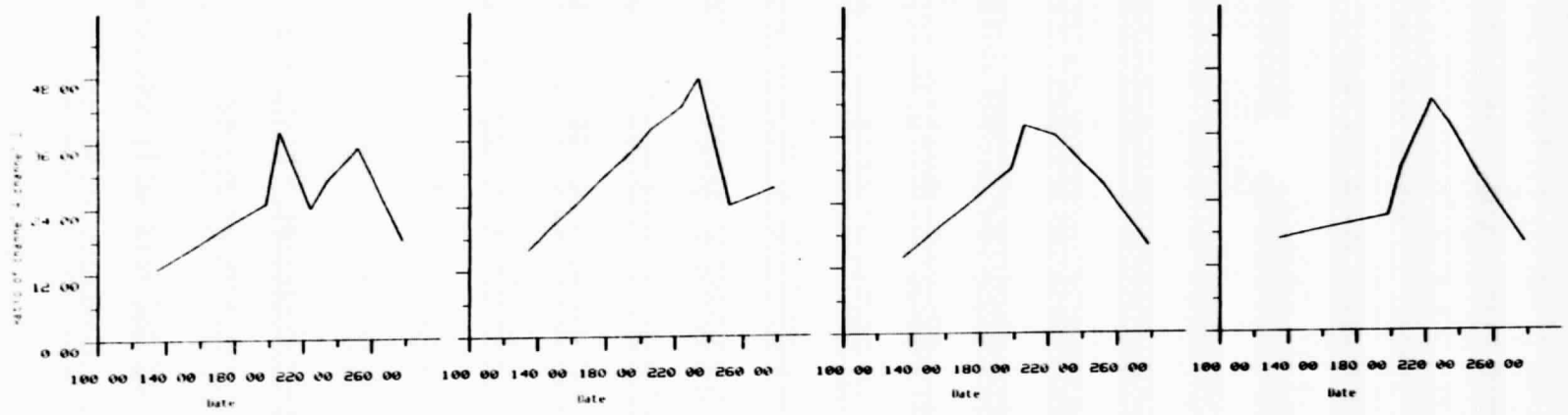


(i) Corn and soybeans.

(j) Corn.

(k) Mixed grains.

(l) Soybeans.



(m) Corn and mixed grains.

(n) Corn and soybeans.

(o) Corn and soybeans.

(p) Corn, soybeans, and homestead.

Figure 3.6-6.- Concluded.

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Cell signatures primarily reflected the variable balance of pure corn and alfalfa Landsat pixel input. The corn signature in this area was quite compact. However, the alfalfa signature was sufficently dispersed so that it precluded an attempt to equate the number of components to the final signature. The chart below gives the number of corn pixels (purity 6) and alfalfa pixels (purity 6) input to each cell signature.

Cell no.	Corn	Alfalfa
1	119	102
2	94	74
3	146	48
4	136	40
5	121	33
6	99	89
7	116	87
8	81	141
9	115	75
10	121	145
11	120	151
12	108	131
13	62	87
14	60	145
15	65	139
16	40	65

Summary

Corn and alfalfa, the two major scene components of this segment, exhibited very different signatures. Field size was average, so each LAC simulation tended to include some percentage of each of these crops. Hence, signature degradation from the pure signatures given in figure 3.6-1 occurred at the cell level; GAC was reasonably homogeneous, but it did not reflect the component crops. Distribution of corn and soybeans was fairly consistent over the segment.

3.7 SAMPLE SEGMENT 828, KANKAKEE COUNTY, ILLINOIS

Sample segment 828, Kankakee County, Illinois, had a scene content of 51 percent corn and 35 percent soybeans. Fields tended to be small, and the area was heavily vegetated. The following acquisitions were merged for processing.

Julian date	Landsat	Comments
78163	2	Trees, and pasture in vigorous growth
78207	3	All vegetation vigorous
78216	2	A few clouds and cloud shadows
78234	2	Corn senescent
78243	3	
78252	2	Corn ripe; soybeans either cut or more vigorous than corn
78271	2	Corn harvested

Major ground cover in the segment was corn or soybeans. These crops (with the composite summer crop combination of both) are illustrated in figures 3.7-1(a) through (c).

The chart below compares the block profiles for this segment.

Block position	A	α	β	t_o
*(001,001)	2.0	19.5	2.2	155 $\pm$ 11.7 days
*(001,069)	2.0	18.9	2.1	155 $\pm$ 1 days
(001,129)	2.1	14.3	1.6	153
*(053,001)	1.9	24.8	2.8	156
*(053,069)	1.9	23.0	2.5	157
(053,129)	1.9	21.8	2.3	157
(065,001)	2.0	24.1	2.7	156
(065,069)	1.9	23.6	2.6	157
(065,129)	1.9	21.6	2.3	157

Data graphs for this site were very similar except for a large nonagricultural area in the upper right quadrant of the scene, which affected the data graph of block position (U01,129). Figure 3.7-2 is a composite of the mean values

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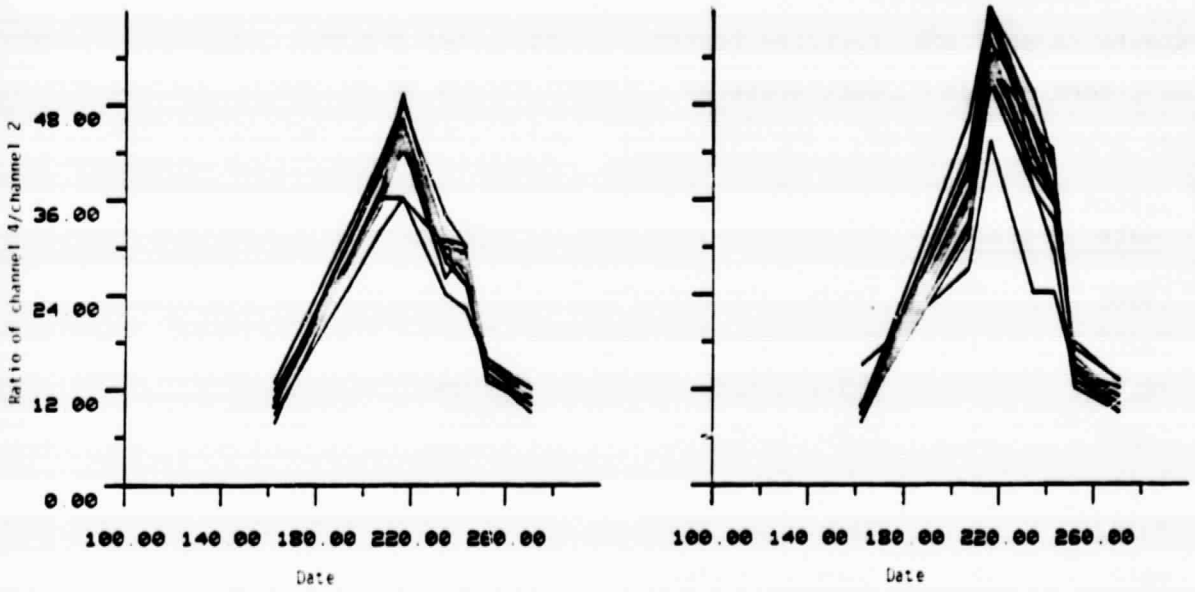
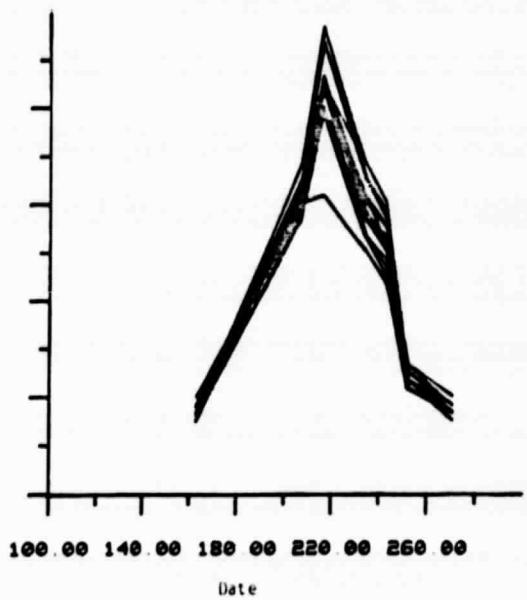


(a) Corn.

(b) Soybeans.



(c) Corn and soybeans.

Figure 3.7-1.- Major crop profiles of sample segment 828.

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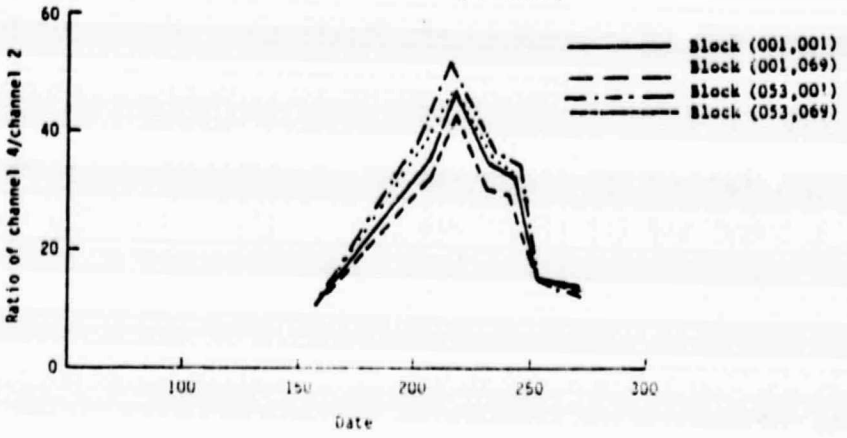
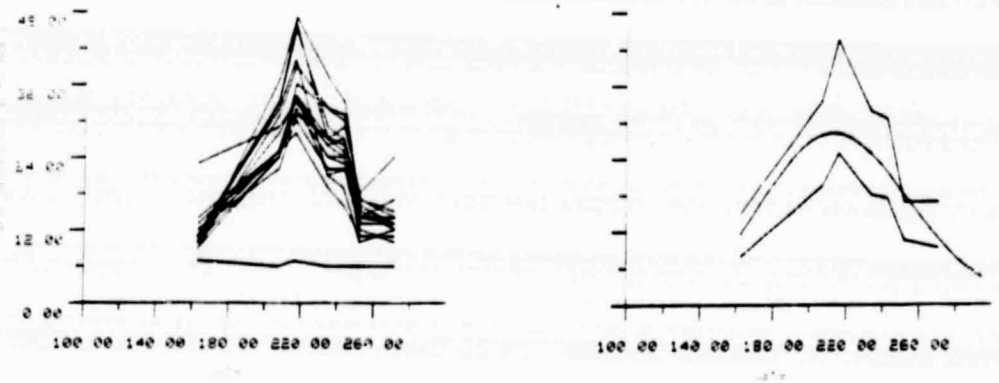
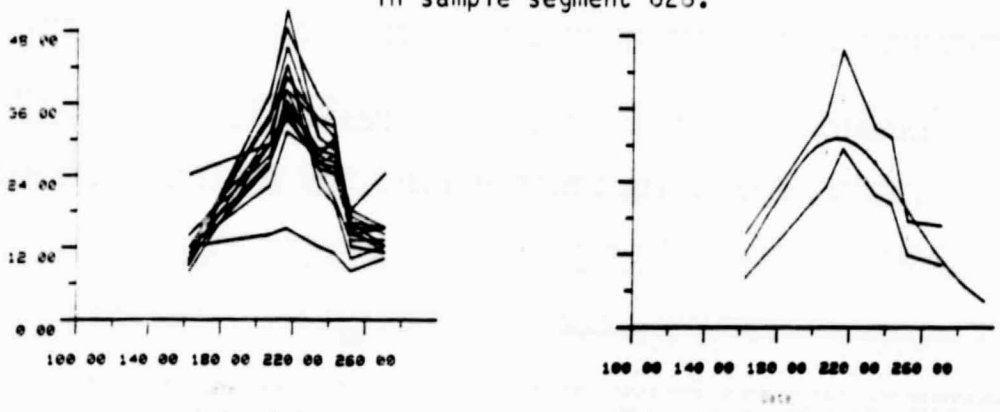


Figure 3.7-2.- Comparison of mean values of block positions (001,001), (001,069), (053,001), and (053,069), in sample segment 828.



(a) Data. (b) Approximating curve.

Figure 3.7-3.- All pixel input for block position (001,129) in sample segment 828.



(c) Data. (b) Approximating curve.

Figure 3.7-4.- Vegetation pixel input for block position (001,129) in sample segment 828.

of the blocks indicated above by asterisks; these blocks covered almost all the segment without overlap.

Figures 3.7-3(a) and (b) illustrate all pixels in block position (001,129). Figures 3.7-4(a) and (b) illustrate the results of applying the nonvegetation filter to the data; 1435 pixels were removed as nonvegetation.

Figure 3.7-5 is the digitized ground truth map covering block position at (001,001). Figure 3.7-6 illustrates the data profiles of the 16 cells in the block position (001,001) with major cell content.

Summary

LAC-scale and GAC-scale coverages are predictably homogeneous for this segment. A large nonagricultural area in the upper right quadrant would be evident on LAC, but it does not alter the GAC-scale profile noticeably.

3.8 SAMPLE SEGMENT 1725, FLATHEAD COUNTY, MONTANA

Sample segment 1725, Flathead County, Montana, had a scene content of 2 percent spring wheat, 12 percent barley, 25 percent trees, 15 percent pasture, and 12 percent hay. The field size was small.

The following acquisitions were merged with the digitized ground truth maps for processing:

Julian date	Landsat	Comments
78165	2	Haze in right half of scene; hay and alfalfa vigorous
78182	2	Grains emergent
78201	2	Data not available
78209	3	Grains vigorous
78210	3	Data not available
78219	2	Some grains harvested
78263	3	Data not available

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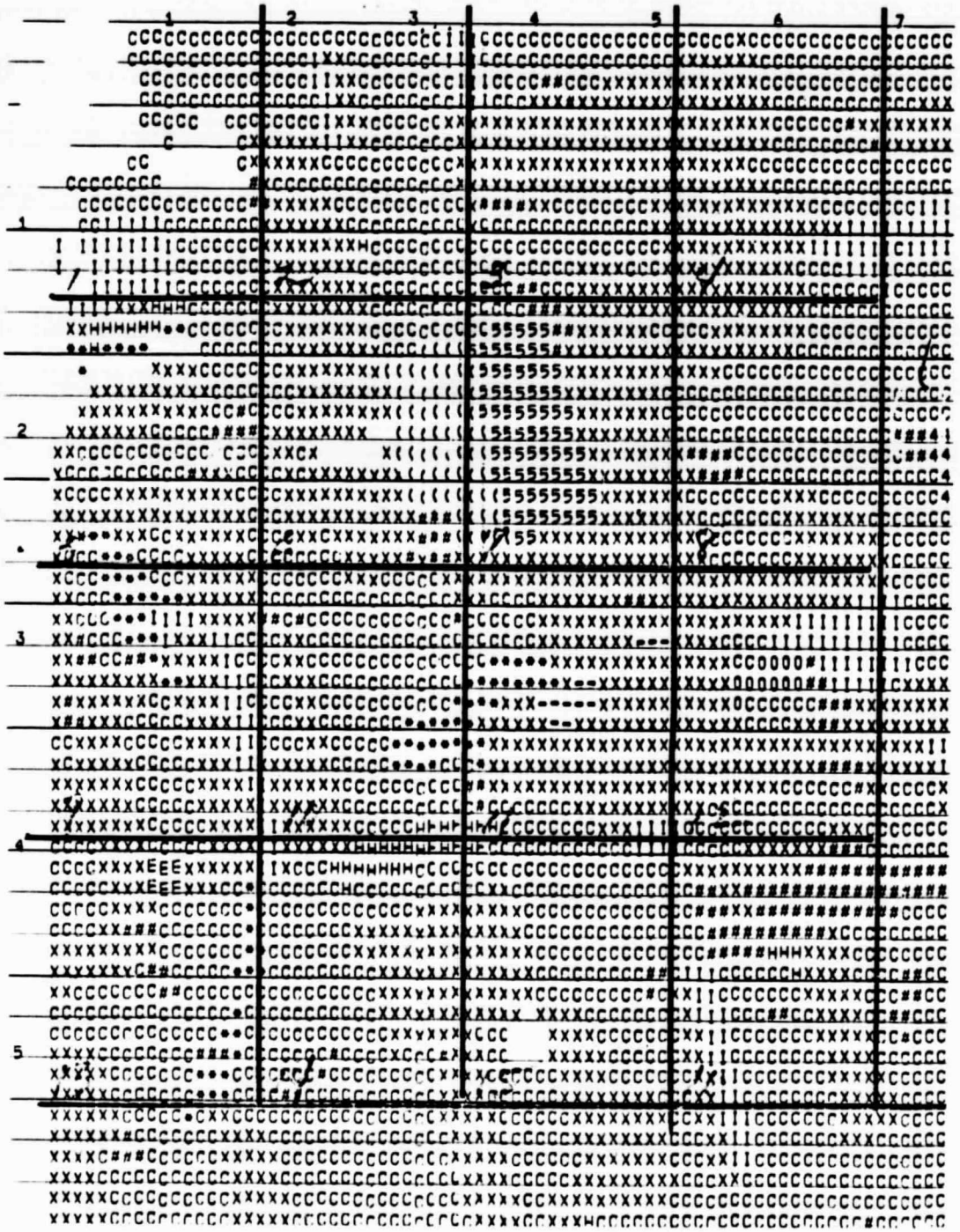
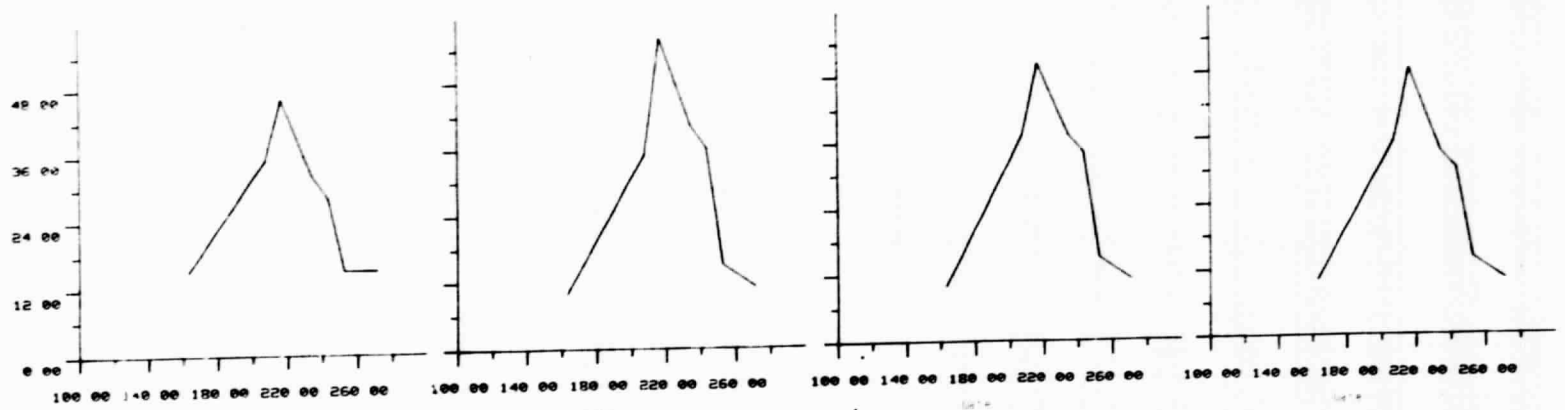


Figure 3.7-5.- The AA digitized ground truth map covering block position (001,001) in sample segment 828.

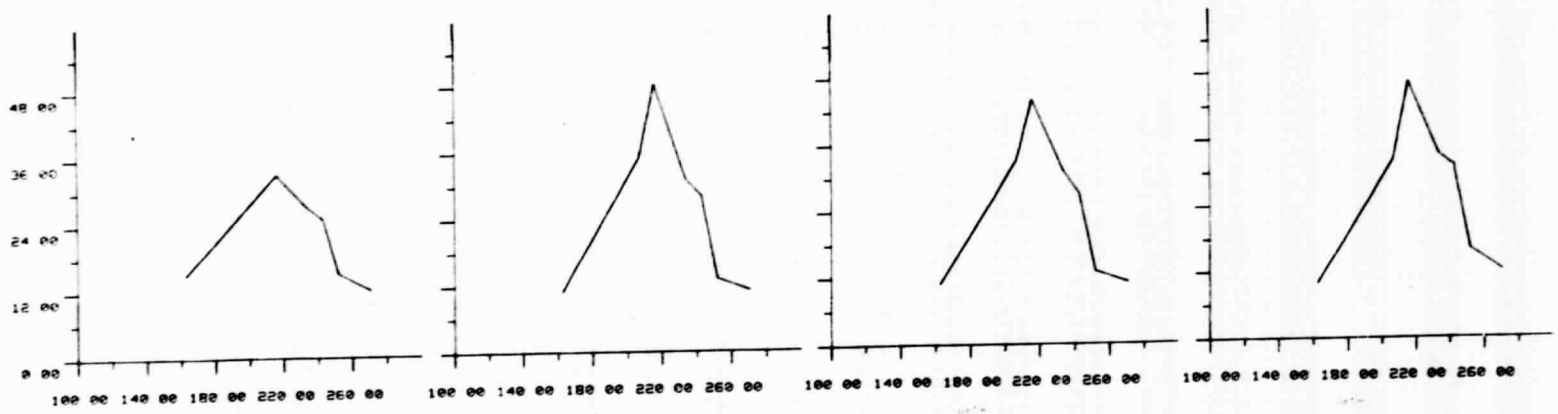


(a) Corn and unidentified.

(b) Corn and unidentified.

(c) Corn and soybeans.

(d) Soybeans and corn.



(e) Corn and alfalfa.

(f) Corn and alfalfa.

(g) Corn and alfalfa.

(h) Corn and alfalfa.

Figure 3.7-6.- The data profiles of the 16 cells in block position (001,001) in sample segment 828.

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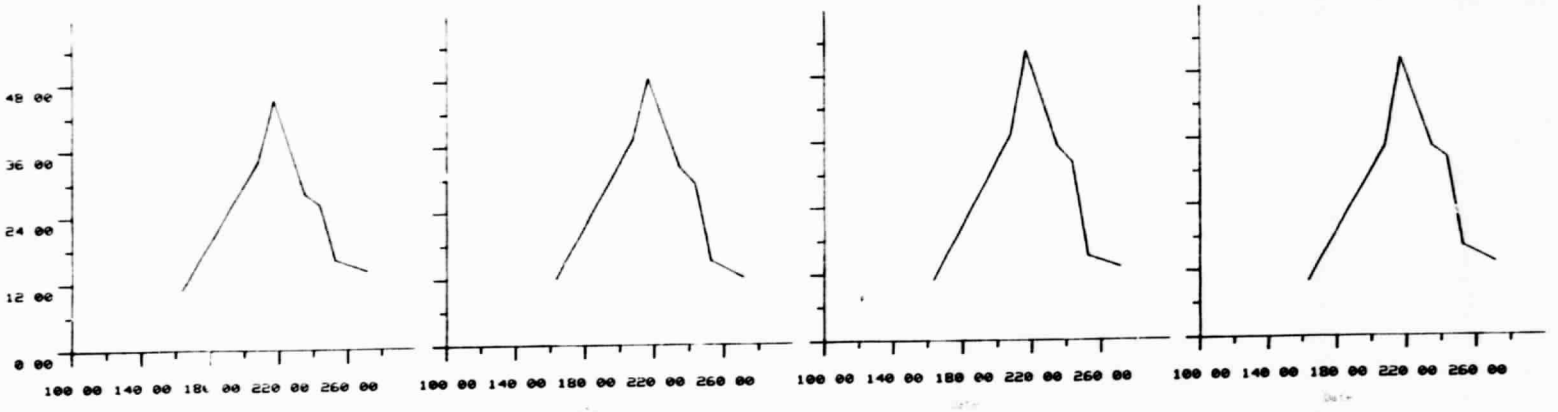
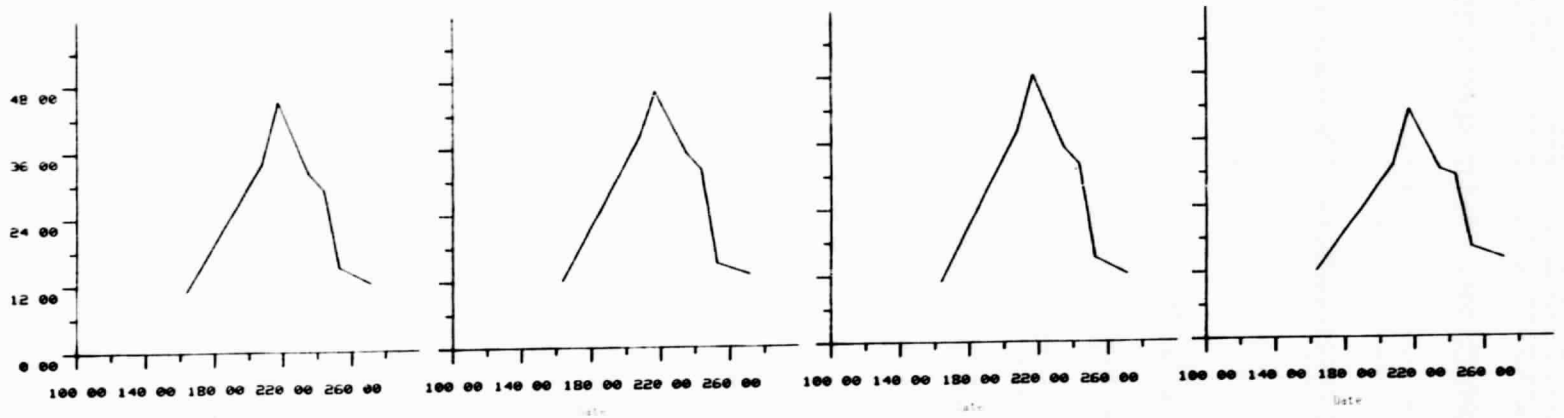


(i) Corn and alfalfa.

(j) Corn and alfalfa.

(k) Corn and alfalfa.

(l) Corn and alfalfa.



(m) Corn, alfalfa, and idle land.

(n) Corn and alfalfa.

(o) Corn, alfalfa, and unidentified.

(p) Corn, alfalfa, and pasture.

Figure 3.7-6.- Concluded.

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Acquisition distribution was poor. Day 78263 was postharvest for small grains, and the early growth stages of grains were not covered by the available acquisitions. Major scene components are illustrated in figures 3.8-1(a), (b), and (c).

The following chart compares the block profiles for the segment. Values A, α, and β are the values of the constants used for approximating the curve fitted to the data; t_o is the estimated emergence data for vegetation in the block.

Block position	A	α	β	t_o
*(001,001)	2.8	1.7	0.3	97 ± 1 day
*(001,069)	Data could not be approximated by a curve			
(001,129)	2.6	2.0	0.3	104 ± 1479 days
*(053,001)	3.3	0.2	0.1	31 ± 112 days
*(053,069)	2.5	3.0	0.4	111
(053,129)	2.4	3.8	0.5	115 ± 1 day
(065,001)	3.3	0.2	0.1	33 ± 1 day
(065,069)	2.4	3.8	0.5	115 ± 10 day
(065,129)	2.4	3.7	0.5	115 ± 1 day

Block position (001,001) generates a typical profile for the segment.

Figures 3.8-2(a) and (b) illustrate all pixels in block position (001,001). Figures 3.8-3(a) and (b) illustrate the results of applying a filter to remove nonvegetation pixels from input to the block mean values. Only 646 of 3536 pixels were filtered out, hence, applying the vegetation filter made little difference.

In general, either the data curve generated for this segment was poor, or the data could not be approximated by a curve. Figure 3.8-4 illustrates the mean values of the data in the blocks indicated above by asterisks. This comparison of the GAC profiles illustrates the homogeneity of the data profiles at the GAC scale.

Figure 3.8-5 is the digitized ground truth map for block position (001,001). Figures 3.8-6(a) through (p) illustrate the data profiles, with major cell content, of the cells for this block.

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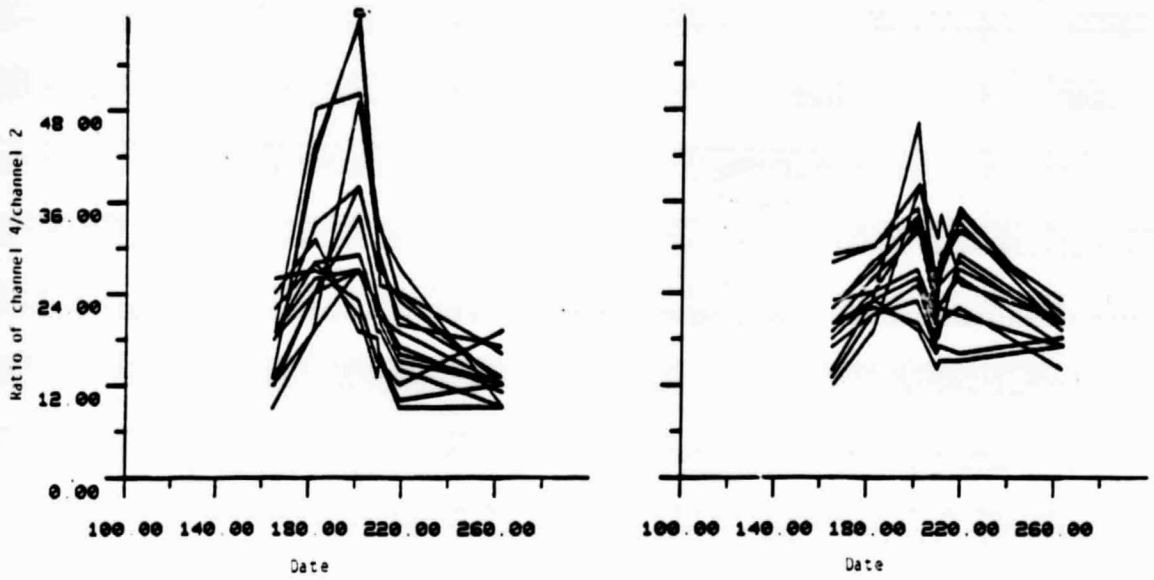
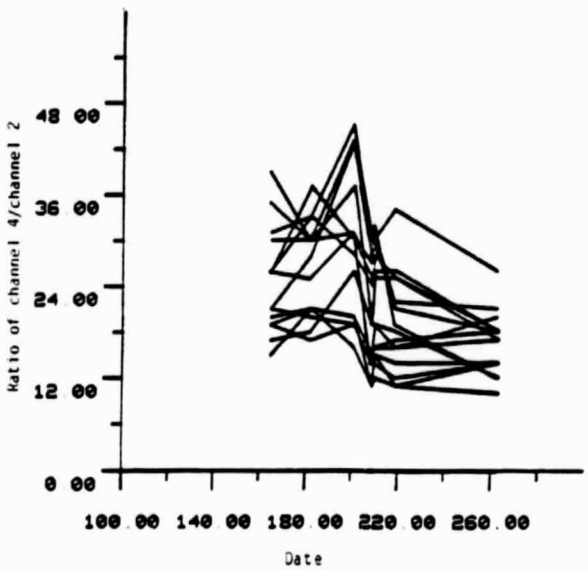


(a) Small grains.

(b) Trees.



(c) Pasture.

Figure 3.8-1.- Major crop profiles of sample segment 1725.

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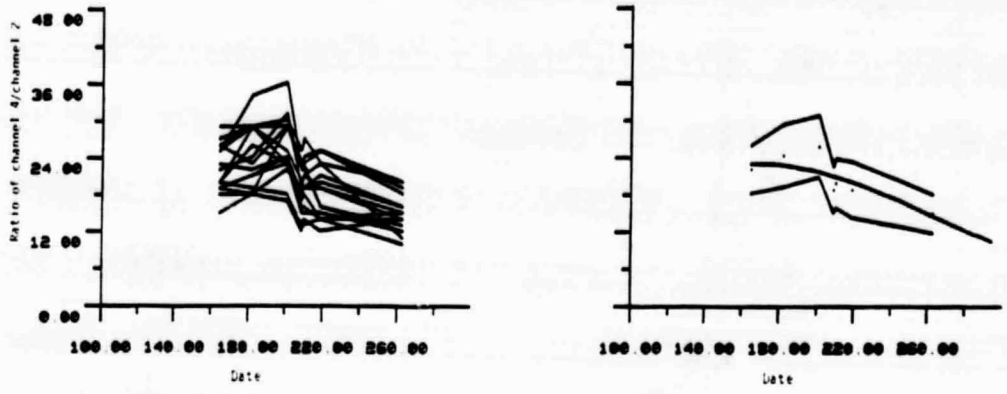
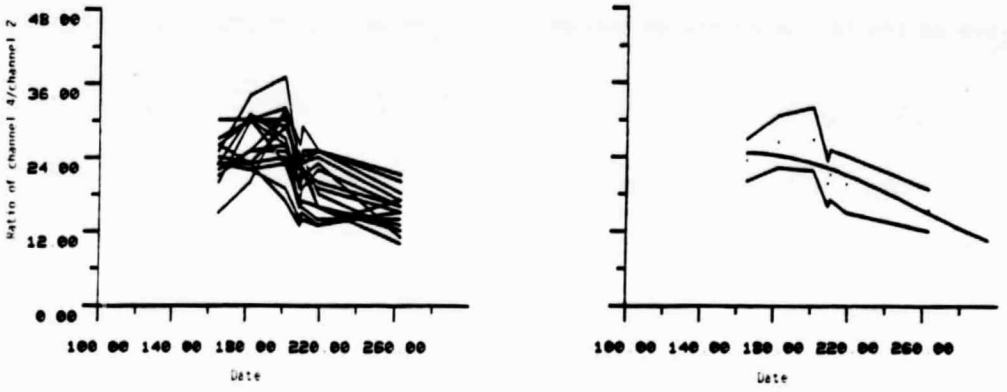


(a) Data. (b) Approximating curve.

Figure 3.8-2.- All pixel input for block position (001,001) in sample segment 1725.



(a) Data. (b) Approximating curve.

Figure 3.8-3.- Vegetation pixel input for block position (001,001) in sample segment 1725.

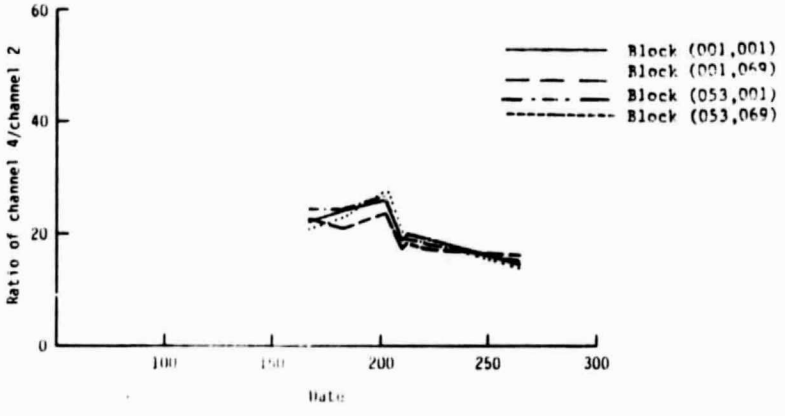


Figure 3.8-4.- Comparison of mean values of block positions (001,001), (001,069), (053,001), and (053,069) in sample segment 1725.

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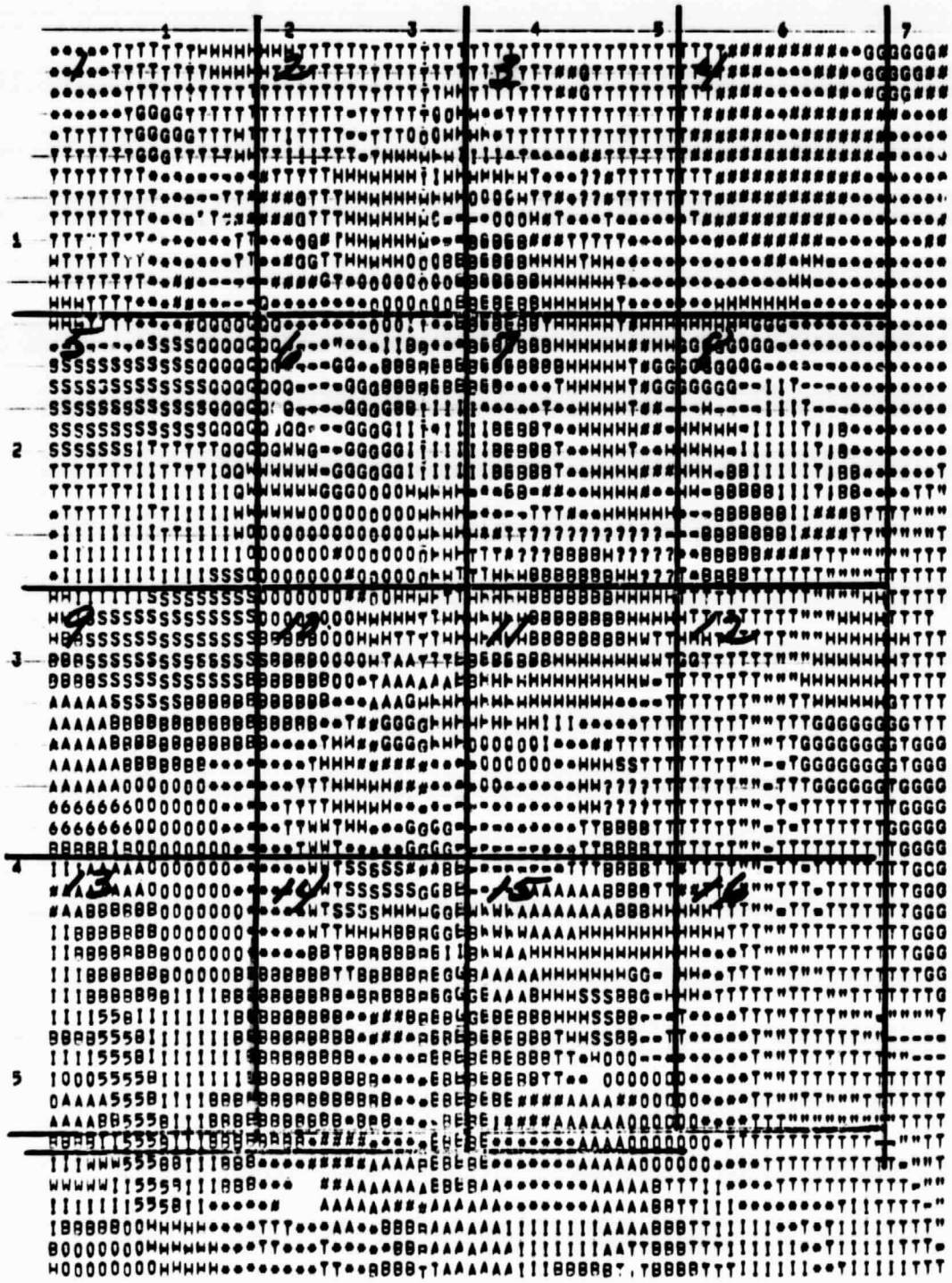
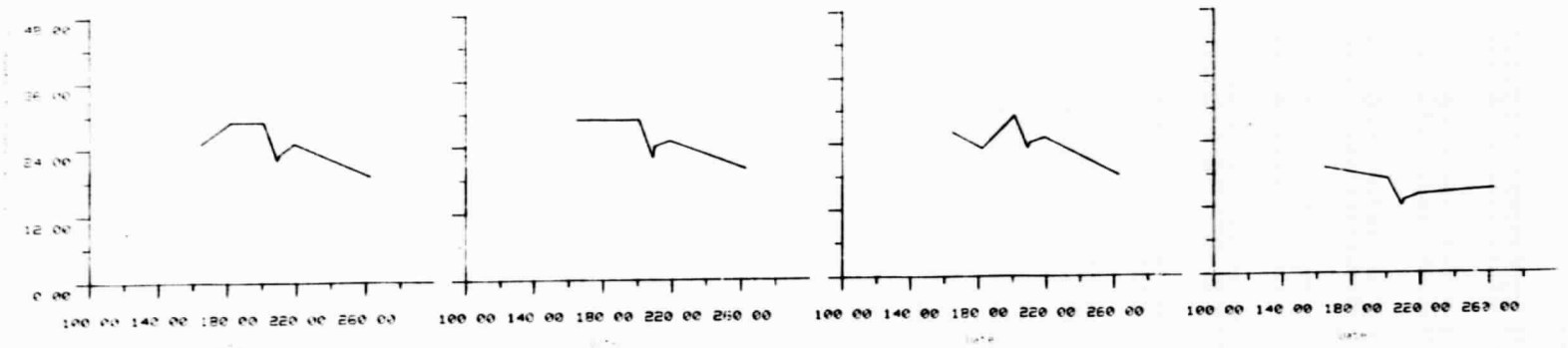


Figure 3.8-5.- The AA digitized ground truth map covering block position (001,001) in sample segment 1725.

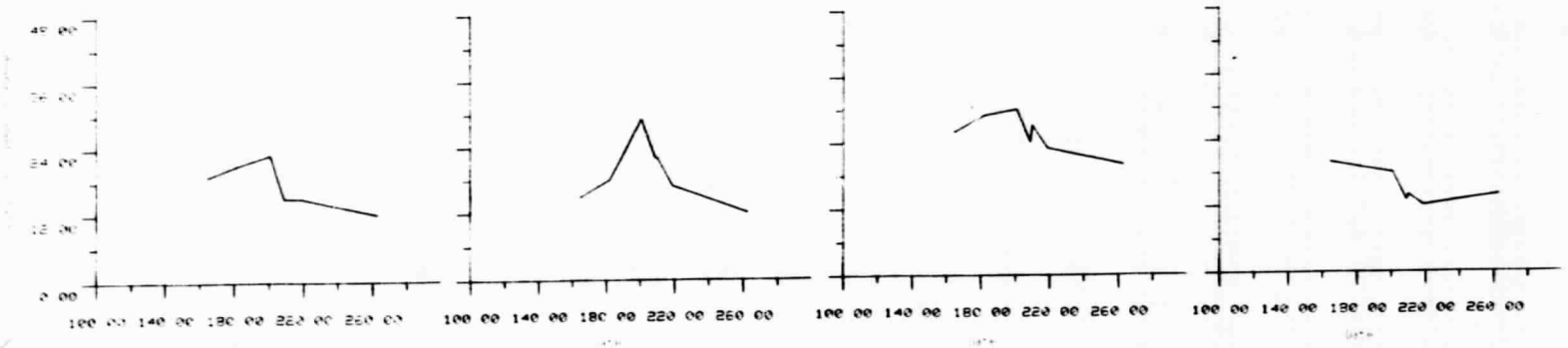


(a) Trees, grass, and pasture.

(b) Trees and hay.

(c) Trees and mixed grains.

(d) Homestead.



(e) Spring grains and idle land.

(f) Spring grains and idle land.

(g) Spring grains and hay.

(h) Grains, pasture, and grass.

Figure 3.8-6.- The data profiles of the 16 cells in block position (001,001) in sample segment 1725.

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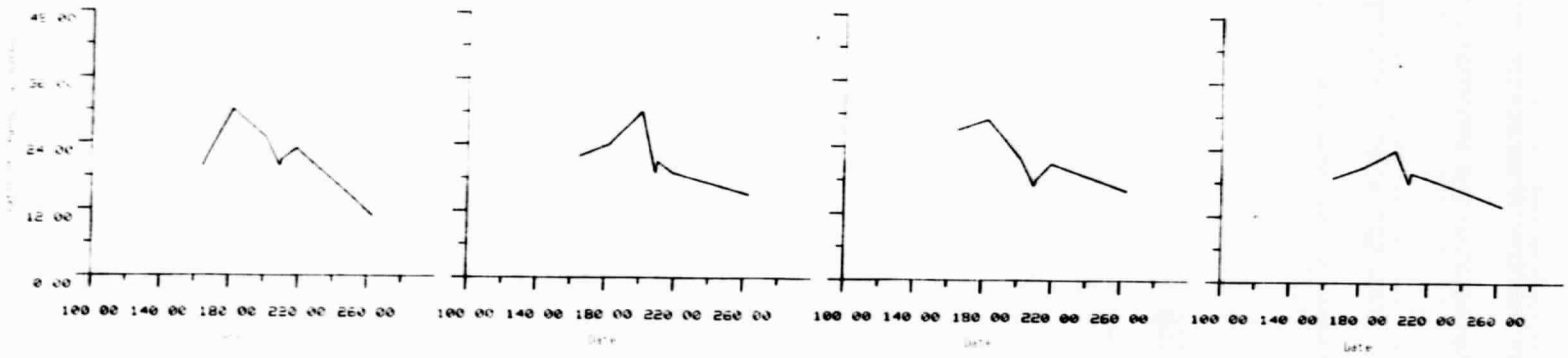
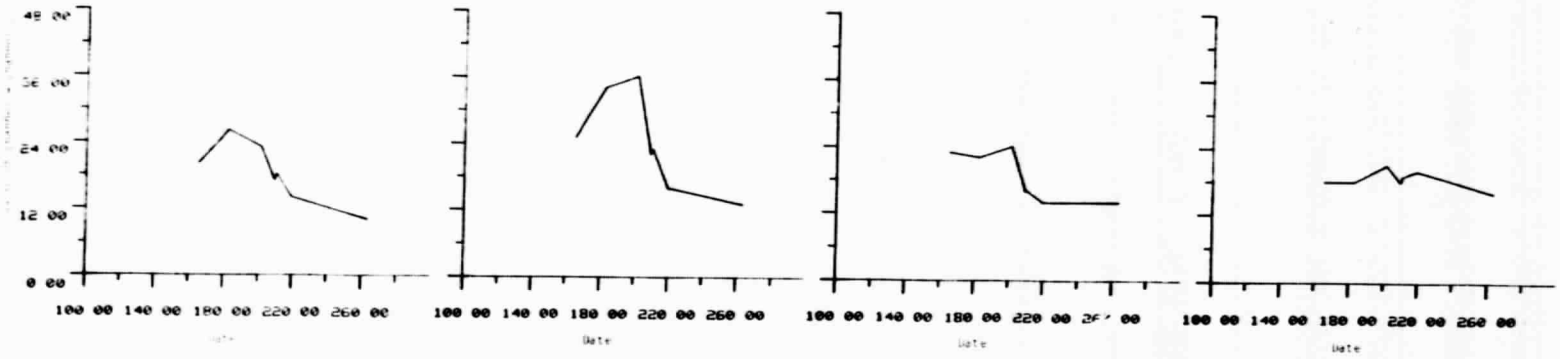


(i) Spring grains and alfalfa.

(j) Mixed grains.

(k) Mixed grains.

(l) Trees and grass.



(m) Spring grains and idle.

(n) Barley.

(o) Mixed grains.

(p) Trees.

Figure 3.8-6.- Concluded.

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Summary

Acquisition distribution in this segment as it relates to the vegetation growth cycle is poor. Small fields and the difference in profile between scene components render LAC-scale coverage unrepresentataive of the components. This is reflected in the GAC-scale simulation. The GAC scale profile is very similar over the segment; it is, however, dissimilar to the component profile.

3.9 SAMPLE SEGMENT 1924, LA MOURE COUNTY, NORTH DAKOTA

Sample segment 1924, La Moure County, North Dakota, had a scene content of 29 percent spring wheat, 6 percent oats and barley, 14 percent pasture, and 10 percent idle cropland; 12 percent of the segment had not been identified ground truth.

The following acquisitions were merged with the digitized ground truth for processing.

Julian date	Landsat	Comments
78136	2	Pasture, alfalfa, and winter grains vigorous
78154	2	One cloud in scene; some spring grain emergent
78208	2	Winter grain harvest; some harvest of barley
78216	3	Some grain cut and harvested
78217	3	
78243	2	Harvest of grains
78270	3	

Data quality for these acquisitions was good, but distribution failed to sample the vigorous growth period of spring grains. Major ground cover was spring grains and pasture; there was also a reasonable amount of acreage in safflowers and sunflowers. Figures 3.9-1(a), (b), and (c) illustrate these profiles; figure 3.9-1(d) is the profile for idle land.

The following chart shows a comparison of the block profiles for segment 1924:

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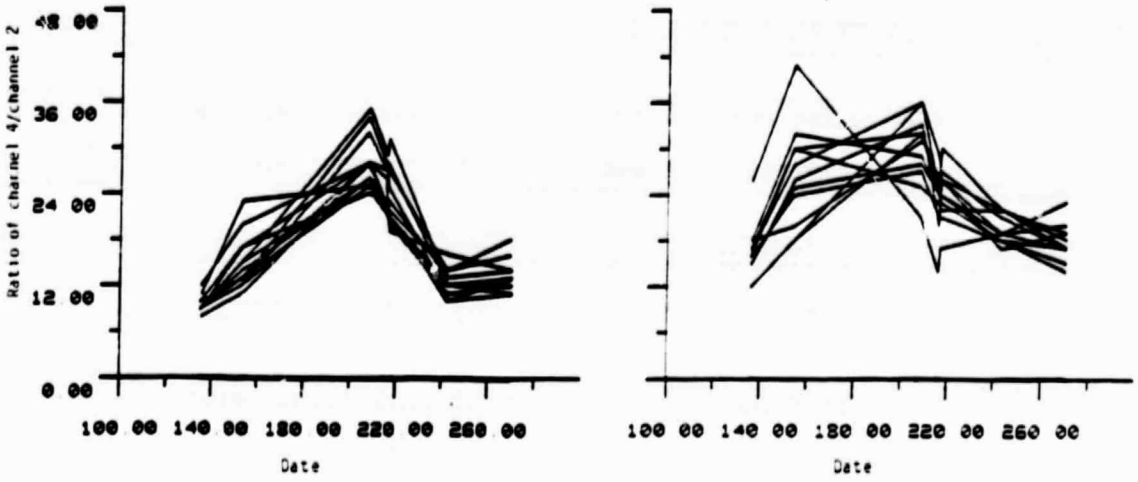
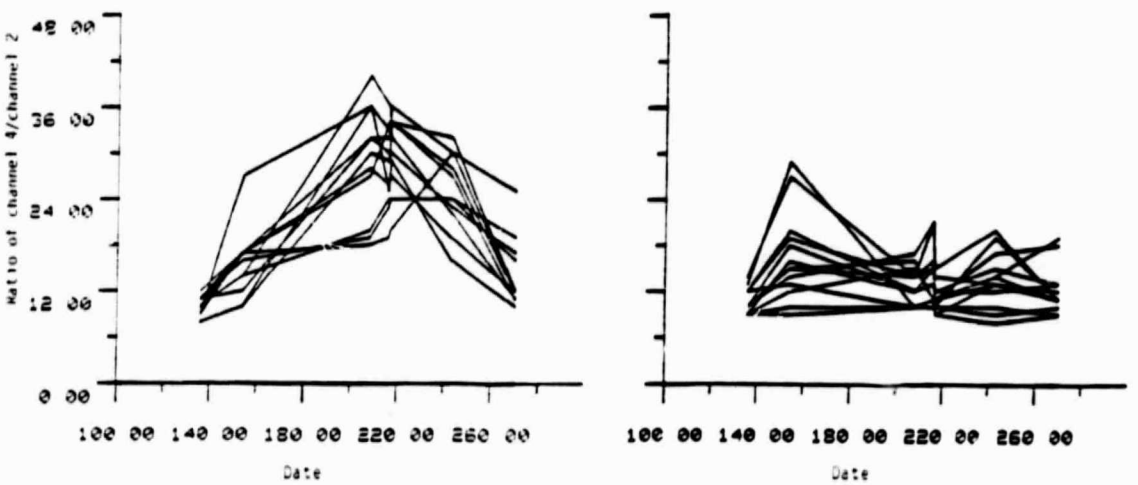


(a) Spring wheat.

(b) Pasture.



(c) Safflowers and sunflowers.

(d) Idle land.

Figure 3.9-1.- Major crop profiles of sample segment 1924.

Block position	A	α	β	t^0
*(001,001)	2.2	5.8	0.7	124
*(001,069)	2.2	6.0	0.8	124 ± 1700 days
(001,129)	2.3	4.6	0.6	122 ± 1 day
*(053,001)	2.2	6.8	0.5	124 ± 2 days
*(053,069)	2.4	3.7	0.5	118
(053,129)	2.2	5.4	0.7	123 ± 2 days
(065,001)	2.2	6.1	0.8	122 ± 2 days
(065,069)	2.5	3.6	0.5	117 ± 251 days
(065,129)	2.2	5.3	0.7	123

These values indicated a difference in block simulation that was not evident in the data graphs. The data were a reasonably consistent mix of pasture and spring wheat. Figure 3.9-2 illustrates the mean values of the data in the block positions marked by asterisks above.

Figures 3.9-3(a) and (b) illustrate all the pixels in block position (053,001). This graph is typical of the blocks in the segment, although it does contain a large amount of water. Figures 3.9-4(a) and (b) illustrate the effects of applying the filter to remove nonvegetation pixels from input to the block mean values; 696 pixels were removed as nonvegetation.

Ground truth for this area is given in figure 3.9-5. Figures 3.9-6(a) through (p) illustrate the data profiles with major cell content for the cells of block position (065,129).

Summary

The lack of acquisitions between days 78154 and 78208 caused indefinite profiles in this segment. LAC-scale simulation was often identifiable as being like pasture or spring wheat. Field size in this segment was good, so LAC sampling can be one component. GAC-scale simulation is consistent over the segment, but component signatures were degraded at this level.

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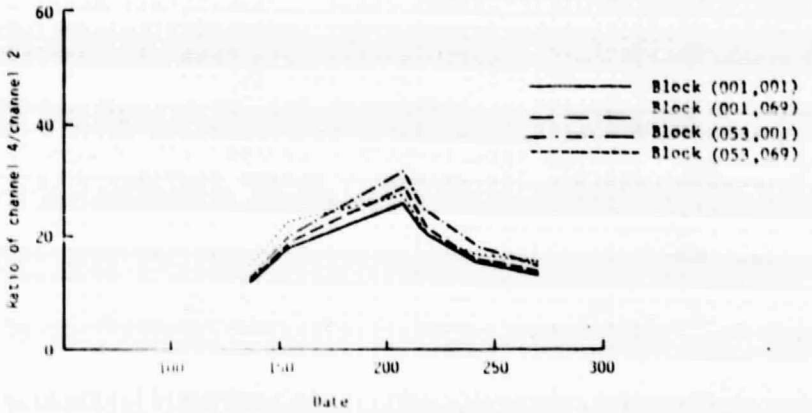
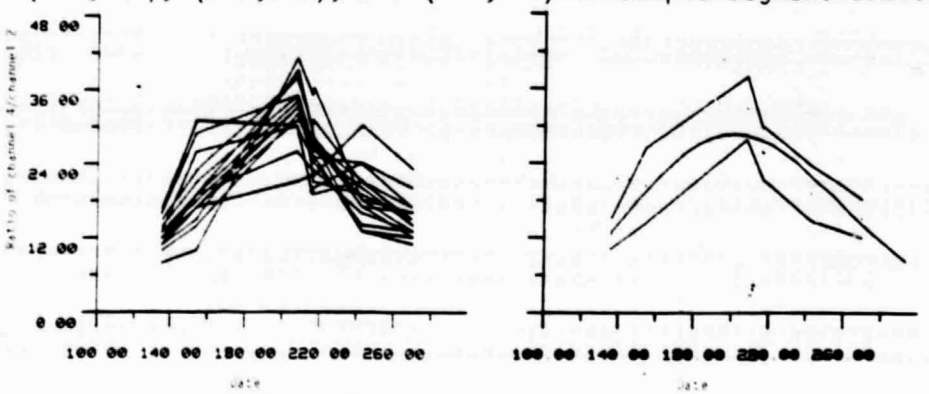
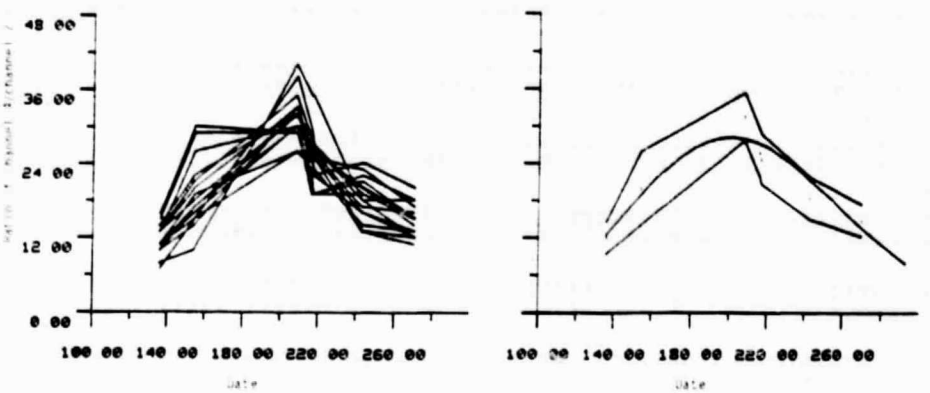


Figure 3.9-2.- Comparison of mean values of block positions (001,001), (001,069), (053,001), and (053,069) in sample segment 1924.



(a) Data. (b) Approximating curve.

Figure 3.9-3.- All pixel input for block position (053,001) in sample segment 1924.



(a) Data. (b) Approximating curve.

Figure 3.9-4.- Vegetation input for block position (053,001) in sample segment 1924.

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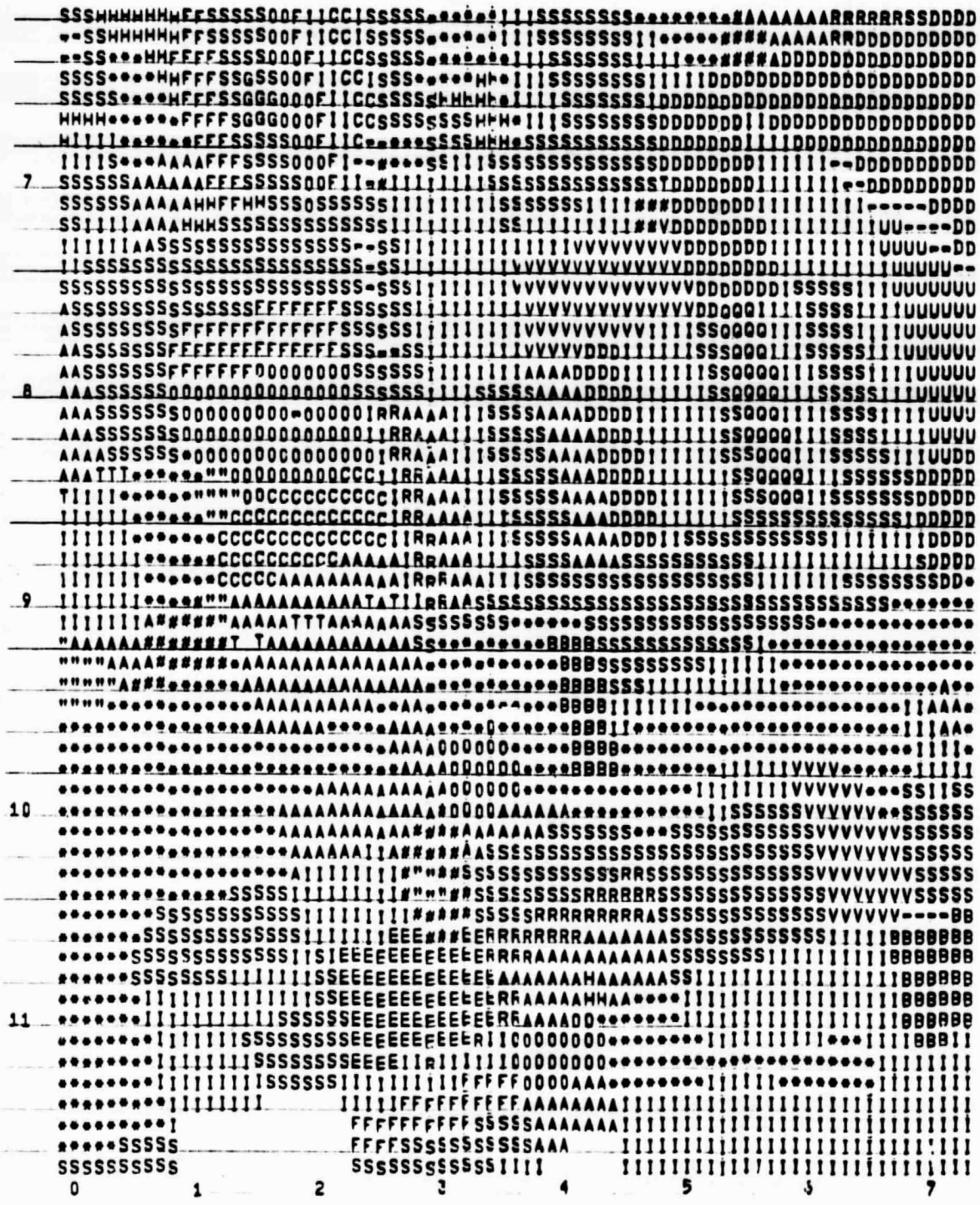
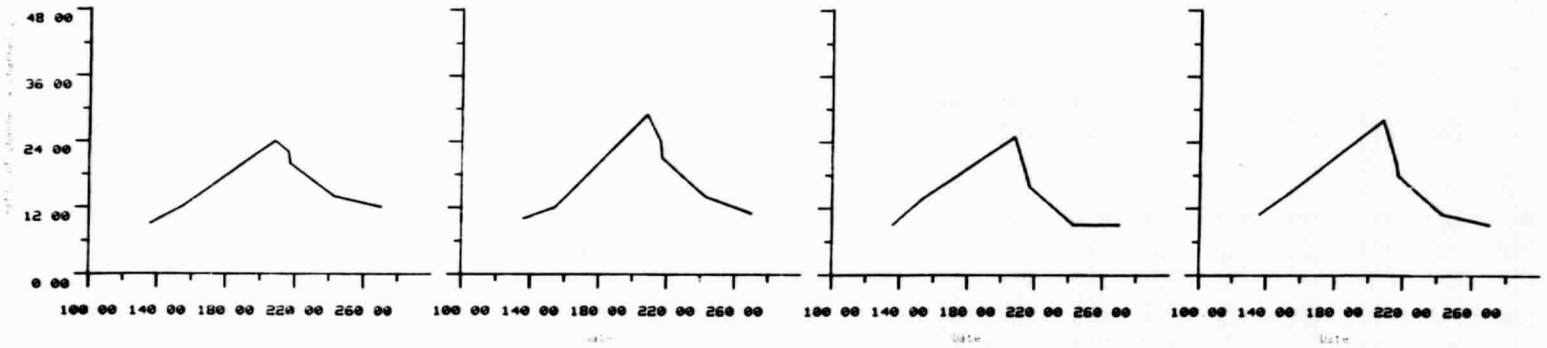
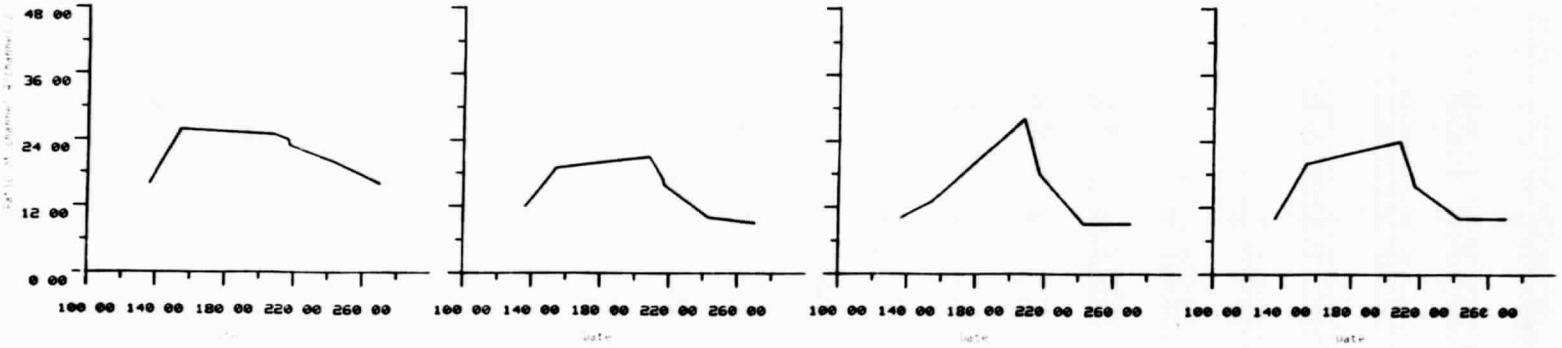


Figure 3.9-5.- The AA digitized ground truth map covering block position (053,001) in sample segment 1924.



(a) Spring wheat, sunflowers, and idle land. (b) Spring wheat and idle land. (c) Spring wheat. (d) Spring wheat and pasture.



(e) Alfalfa and spring wheat. (f) Spring wheat and idle land. (g) Spring wheat. (h) Spring wheat.

Figure 3.9-6.- The data profiles of the 16 cells in block position (065,129) in sample segment 1924.

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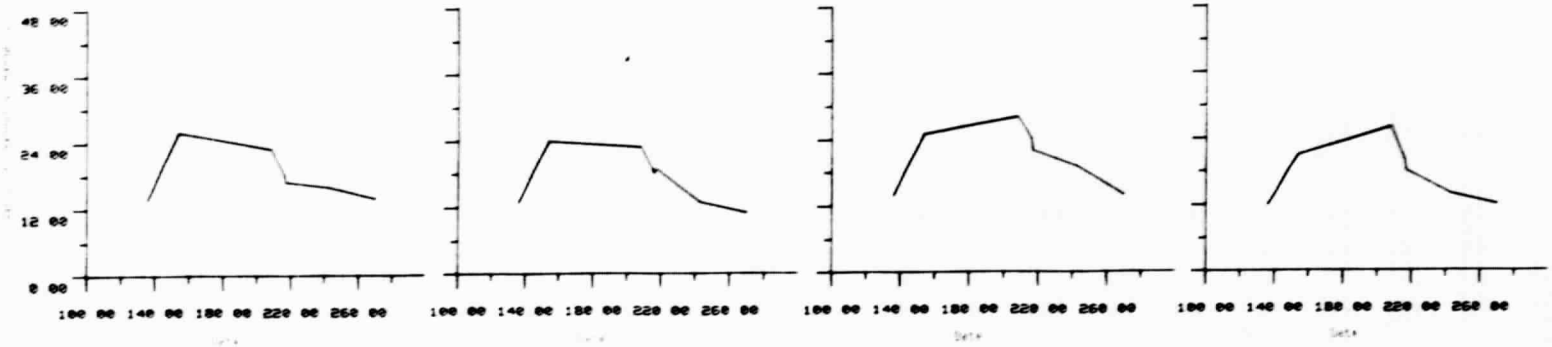
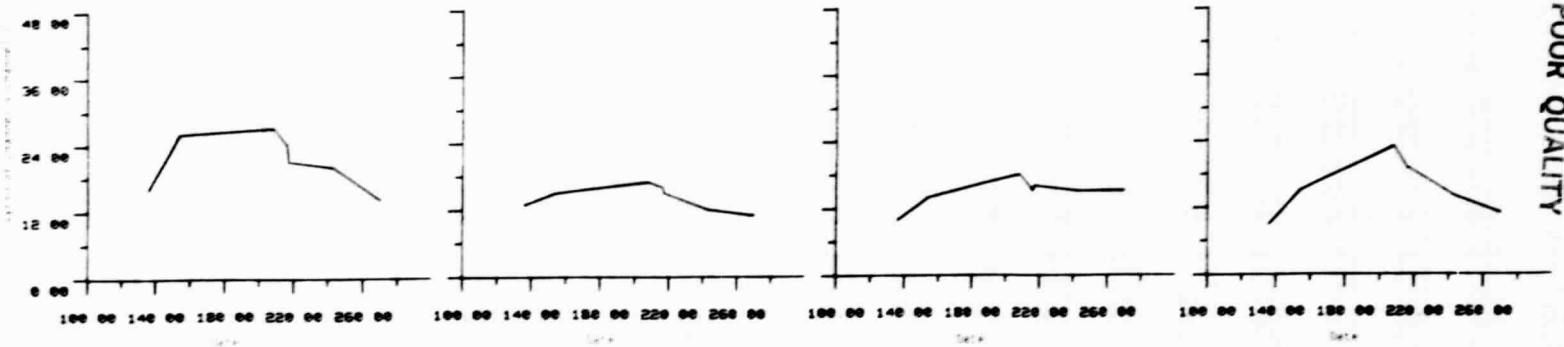


(i) Pasture and spring grains.

(j) Pasture and spring grains.

(k) Pasture and spring grains.

(l) Pasture and spring grains.



(m) Mixed grains.

(n) Idle land.

(o) Idle land and barley

(p) Spring wheat.

Figure 3.9-6.- Concluded.

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3.10 SAMPLE SEGMENT 1253, SEQUOYAH COUNTY, OKLAHOMA

Sample segment 1253, Sequoyah County, Oklahoma, had a scene content of 33 percent soybeans, 27 percent pasture, and 11 percent trees. Field size was good, and pure LAC cells of scene components appeared. Blocks tended to exhibit "recognizable" signatures. The presence of spring vegetation, pasture and trees, summer vegetation, and soybeans required alteration of the curve fitting program. The acquisitions below were well distributed over the spring growth cycle, and all seven acquisitions were used to fit the approximating curve. For soybeans, the acquisition gap between days 184 and 274 coincided with the peak growth period of soybeans; it did not provide a good distribution, and the curve fit was to the final five acquisitions.

The following acquisitions were merged:

Julian date	Landsat	Comments
78076	2	Alfalfa vigorous in some areas
78130	2	Pasture and trees in vigorous growth
78165	2	Soybeans emergent
78166	2	
78184	2	Soybeans vigorous
78274	2	Some soybeans harvested; pasture senescent
78291	2	

The major scene components of soybeans, pasture, and trees are illustrated in figures 3.10-1(a), (b), and (c).

The following chart is a comparison of the block profiles for this segment, which were taken from the curve fitted to seven acquisitions.

Block position	A	α	β	t_o
*(001,001)	2.6	2.6	0.4	101
*(001,069)	2.1	3.6	0.4	104
(001,129)	2.1	2.2	0.2	110
*(053,001)	2.6	2.6	0.4	100

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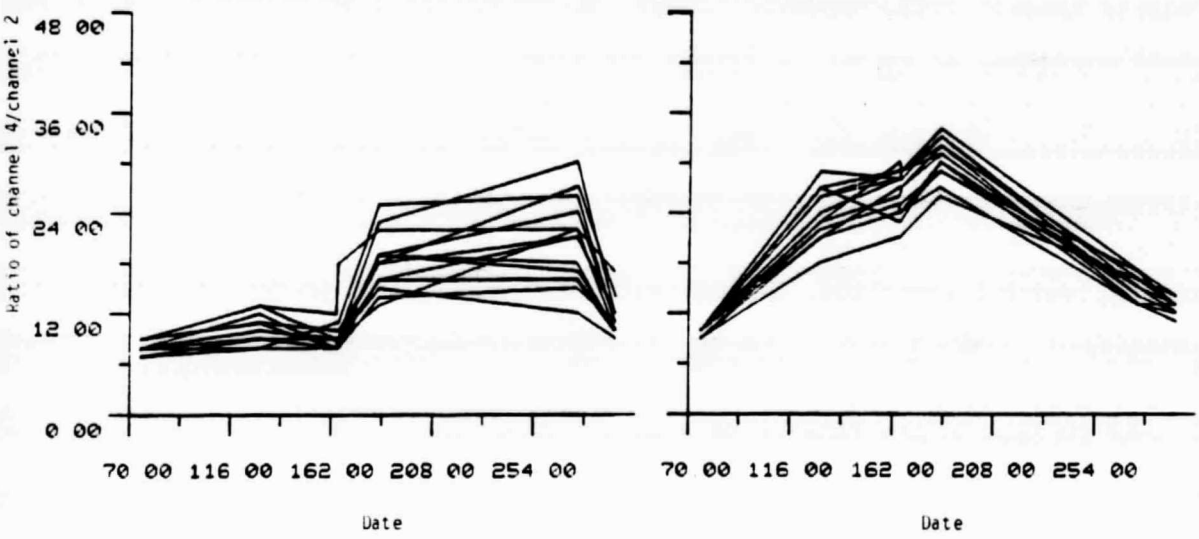
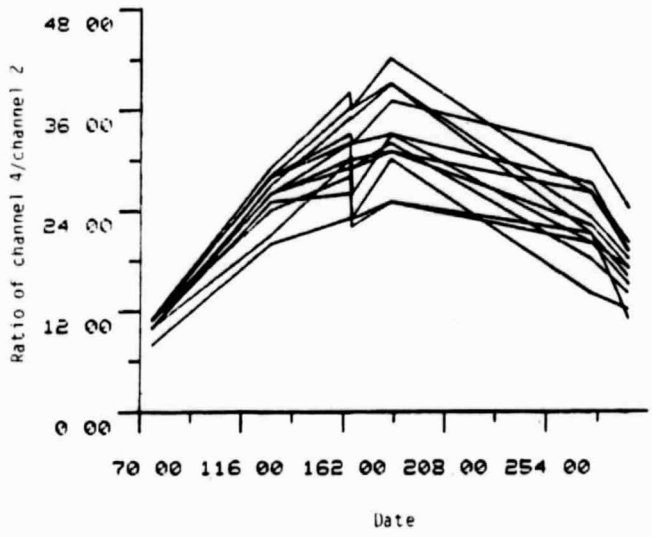


(a) Soybeans.

(b) Pasture.



(c) Trees.

Figure 3.10-1.- Major crop profiles of sample segment 1253.

Block position	A	α	β	t_o
*(053,069)	2.3	2.0	0.2	103
(053,129)	1.9	3.4	0.4	106
(065,001)	2.5	2.4	0.3	92
(065,069)	2.1	2.4	0.3	107
(065,129)	1.8	3.6	0.4	107

The GAC simulation was remarkably like the pure signatures of figures 3.10-1(a), (b), and (c); therefore, no overall representative signature can be chosen. Blocks look like pasture and trees or soybeans. Figure 3.10-2 illustrates the mean values of the data in the acquisitions above that are marked with asterisks.

Applying the nonvegetation filter to block position (001,001), which contains a large homestead area, eliminated 1108 of the 3536 pixels. Figures 3.10-3(a) and (b) and 3.10-4(a) and (b) illustrate the effects of applying the filter. Curve approximations were almost identical.

Figure 3.10-5 is the AA digitized ground truth map for block position (001,069). This block position was used for the cells illustrated in figures 3.10-6(a) through (p) with major cell content.

Summary

This was an interesting segment. The degradation of LAC and GAC signatures was minimal despite two vegetation signatures which were quite different. Both GAC-and LAC-simulated coverage retained recognizable vegetation signatures.

3.11 SAMPLE SEGMENT 1075, HOWARD COUNTY, NEBRASKA

Sample segment 1075, Howard County, Nebraska, had a scene content of 28 percent corn and 40 percent pasture. Acquisition coverage was well distributed relative to the vegetation growth cycle in this area. The curve fit on most of the graphs was done to seven acquisitions; however, the curve fit to pure corn was more successful for only the last five acquisitions that were used to fit the curve. The following acquisitions were merged.

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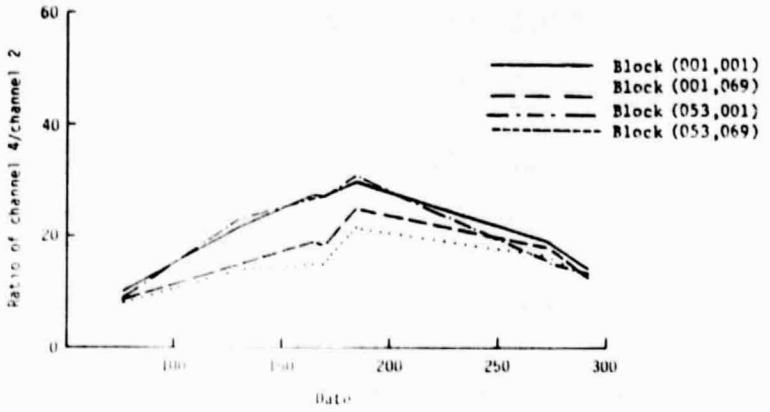
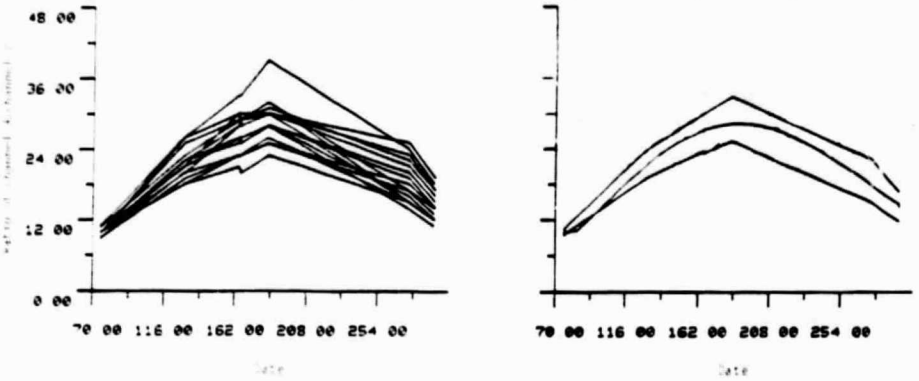
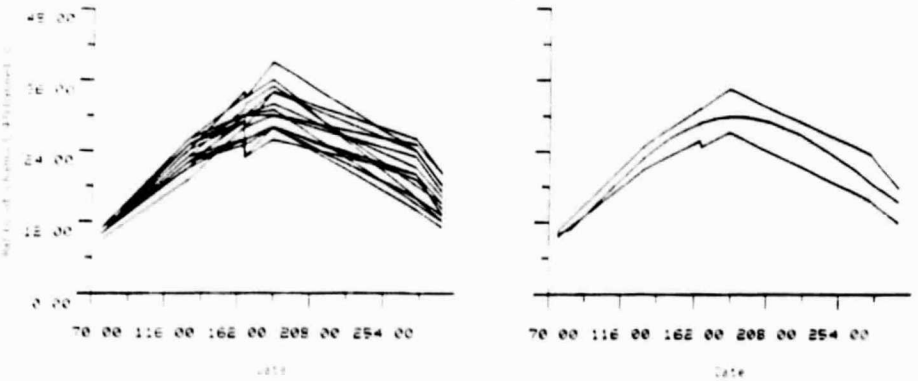


Figure 3.10-2.- Comparison of mean values of block positions (001,001), (001,069), (053,001), and (053,069) in sample segment 1253.



(a) Data. (b) Approximating curve.

Figure 3.10-3.- All pixel input for block position (001,001) in sample segment 1253.



(a) Data. (b) Approximating curve.

Figure 3.10-4.- Vegetation pixel input for block position (001,001) in sample segment 1253.

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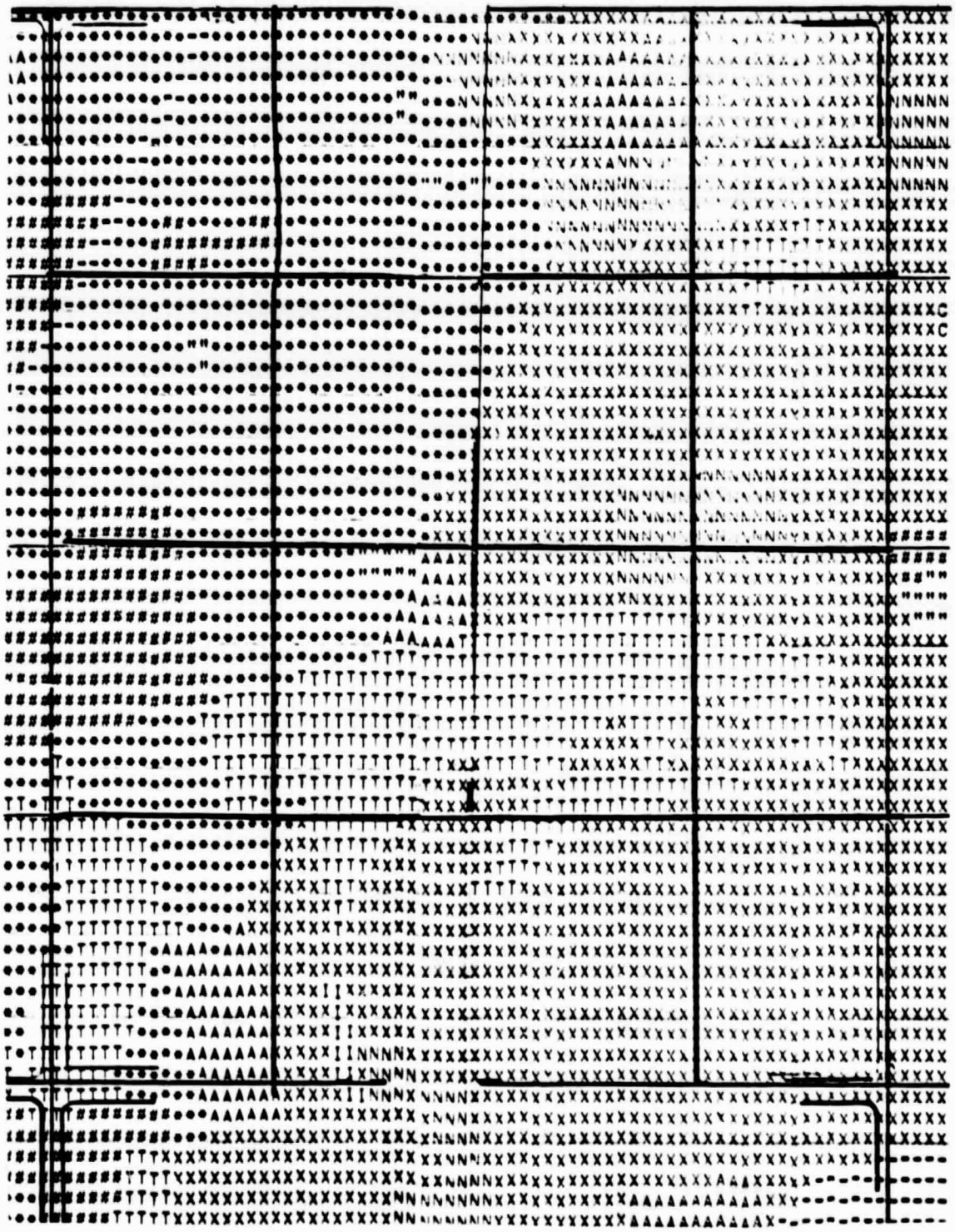
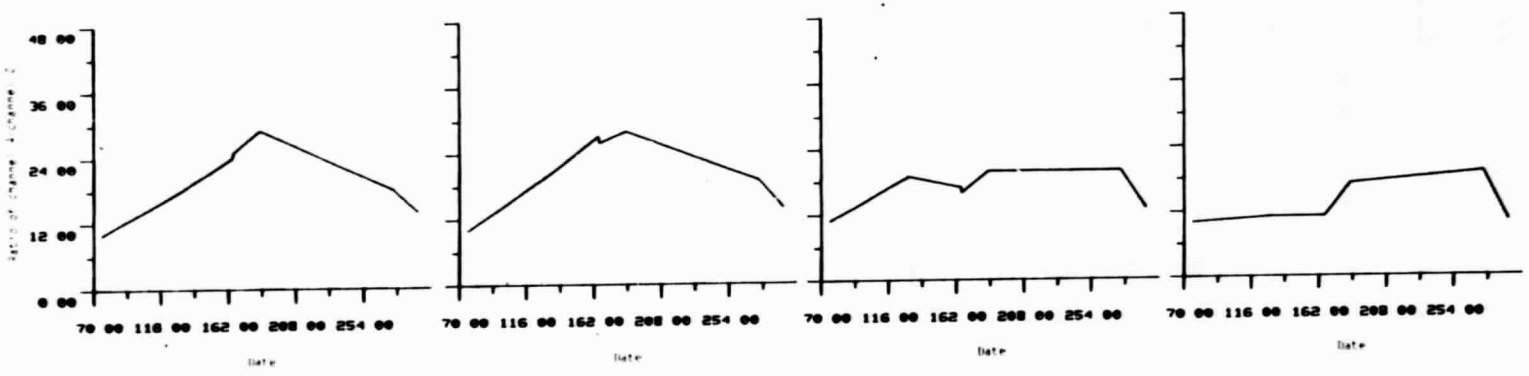
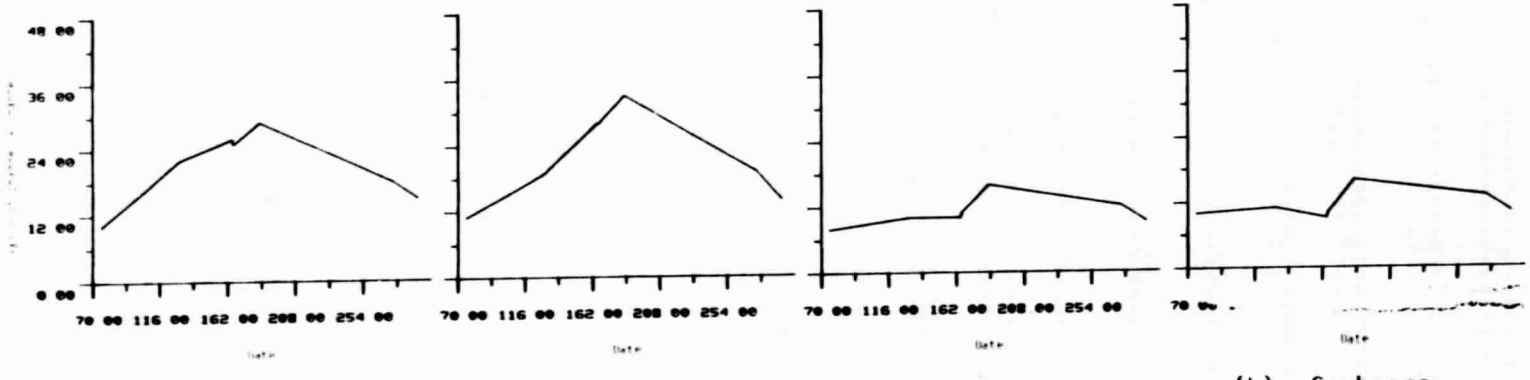


Figure 3.10-5.- The AA digitized ground truth map covering block position (001,069) in sample segment 1253.



(a) Pasture. (b) Pasture. (c) Soybeans, alfalfa, and pasture. (d) Soybeans.



(e) Pasture. (f) Pasture. (g) Soybeans. (h) Soybeans.

Figure 3.10-6.- The data profiles of the 16 cells in block position (001,069) in sample segment 1253.

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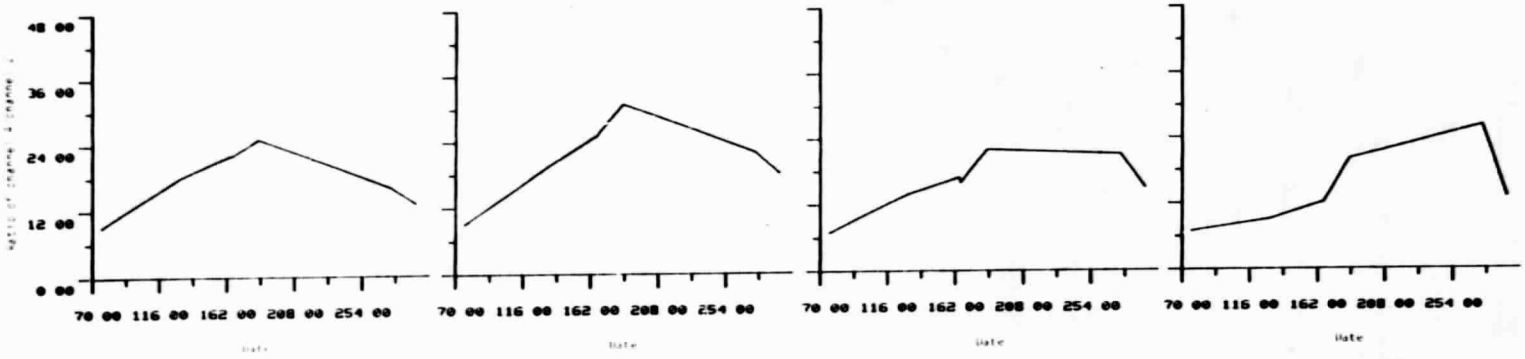
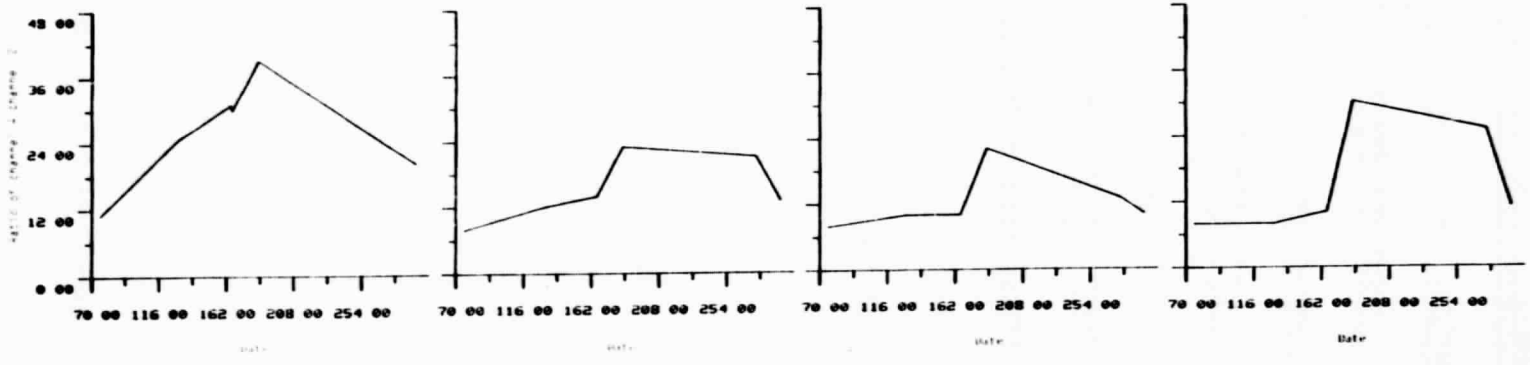


(i) Homestead, trees, and pasture.

(j) Trees and pasture.

(k) Trees and soybeans.

(l) Soybeans.



(m) Trees, soybeans, and alfalfa.

(n) Soybeans.

(o) Soybeans.

(p) Soybeans.

Figure 3.10-6.- Concluded.

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Julian date	Landsat	Comments
78133	2	
78134	2	
78169	2	Pasture and trees vigorous; corn and barley emerged
78188	2	Cloud in upper left corner
78206	2	
78224	2	Corn vigorous
78259	2	Some harvest of corn

Field size was good, and relatively pure signatures of the component crops were produced scaled to LAC. This is reflected in the GAC profiles. Major crop profiles are illustrated in figures 3.11-1(a) through (d).

The following chart compares the block profiles for this segment. Values A, α, and β are values of the constants in the equation of the curve fitted to the data; t_o is the estimated emergence date for vegetation.

Block position	A	α	β	t_o
*(001,001)	2.1	5.4	0.6	121 ± 17
*(001,069)	2.5	3.7	0.5	115 ± 24
(001,129)	2.4	3.3	0.4	117 ± 2
*(053,001)	2.2	4.8	0.6	121 ± 1
*(053,069)	2.5	4.1	0.6	121 ± 1
(053,129)	2.3	4.1	0.5	119 ± 1
(065,001)	2.2	4.8	0.6	121
(065,069)	2.5	4.0	0.6	116
(065,129)	2.4	3.5	0.5	117 ± 4

The different component crop profiles were reflected in different GAC profiles which were like pasture and trees or corn. There really was no representative signature for the segment. Figure 3.11-2 illustrates the data mean values for the block positions marked with asterisks above.

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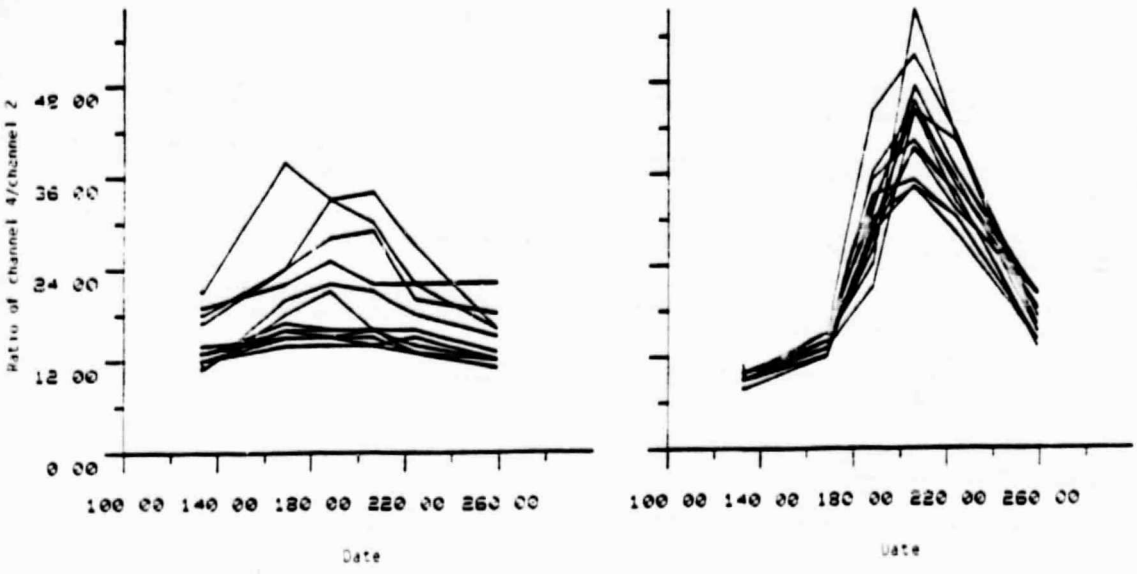
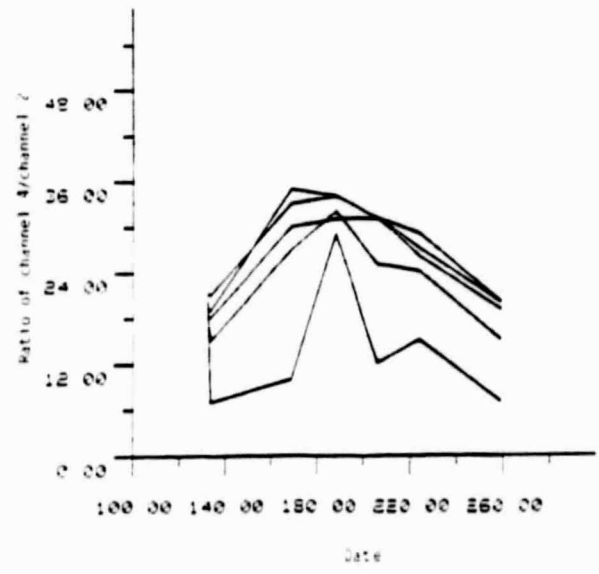
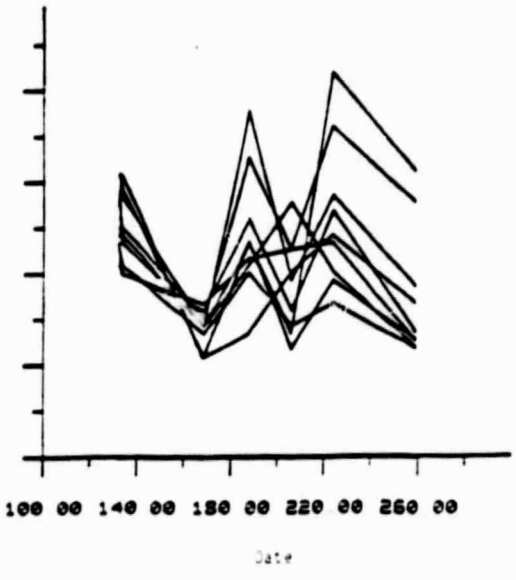


(a) Pasture.

(b) Corn.



(c) Trees.



(d) Alfalfa.

Figure 3.11-1.- Major crop profiles of sample segment 1075.

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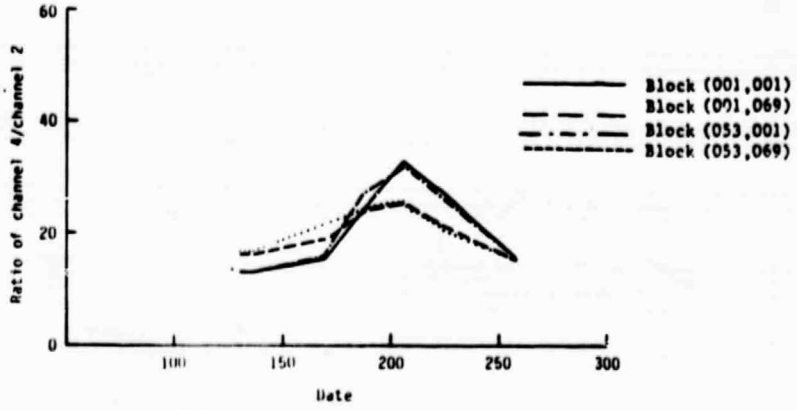
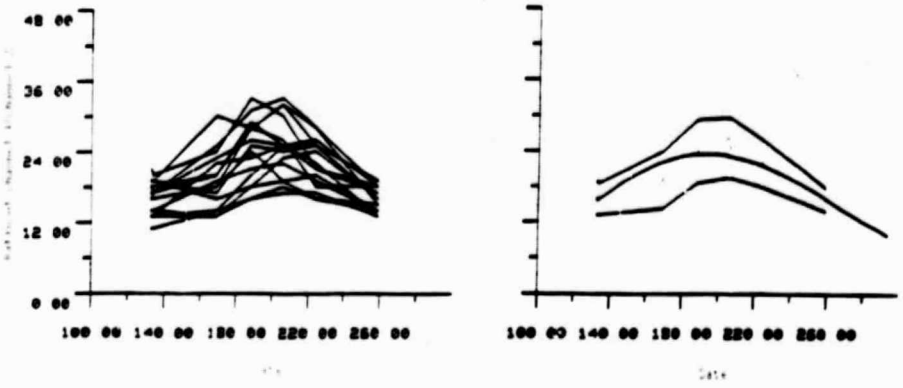
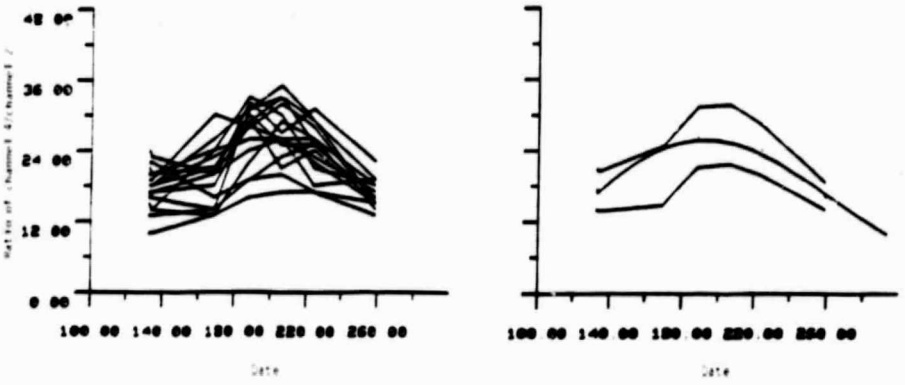


Figure 3.11-2.- Comparison of mean values of block positions (001,001), (001,069), (053,001), and (053,069) in sample segment 1075.



(a) Data. (b) Approximating curve.

Figure 3.11-3.- All pixel input for block position (001,069) in sample segment 1075.



(a) Data. (b) Approximating curve.

Figure 3.11-4.- Vegetation pixel input for block position (001,069) in sample segment 1075.

Applying the vegetation filter to block position (001,069) removed 755 of the 3536 pixels. Figures 3.11-3(a) and (b) illustrate all pixels in block position (001,069); figures 3.11-4(a) and (b) illustrate the results of applying the vegetation filter.

LAC simulation was done in block position (001,001). Figure 3.11-5 is the digitized ground truth map for this area. Figures 3.11-6(a) through (p) illustrate the data profiles of the 16 cells with major cell components.

Summary

Signature degradation was not a problem in this segment. Field size was large and relatively pure LAC-scale cells existed. GAC-scale signatures also were like pasture or corn.

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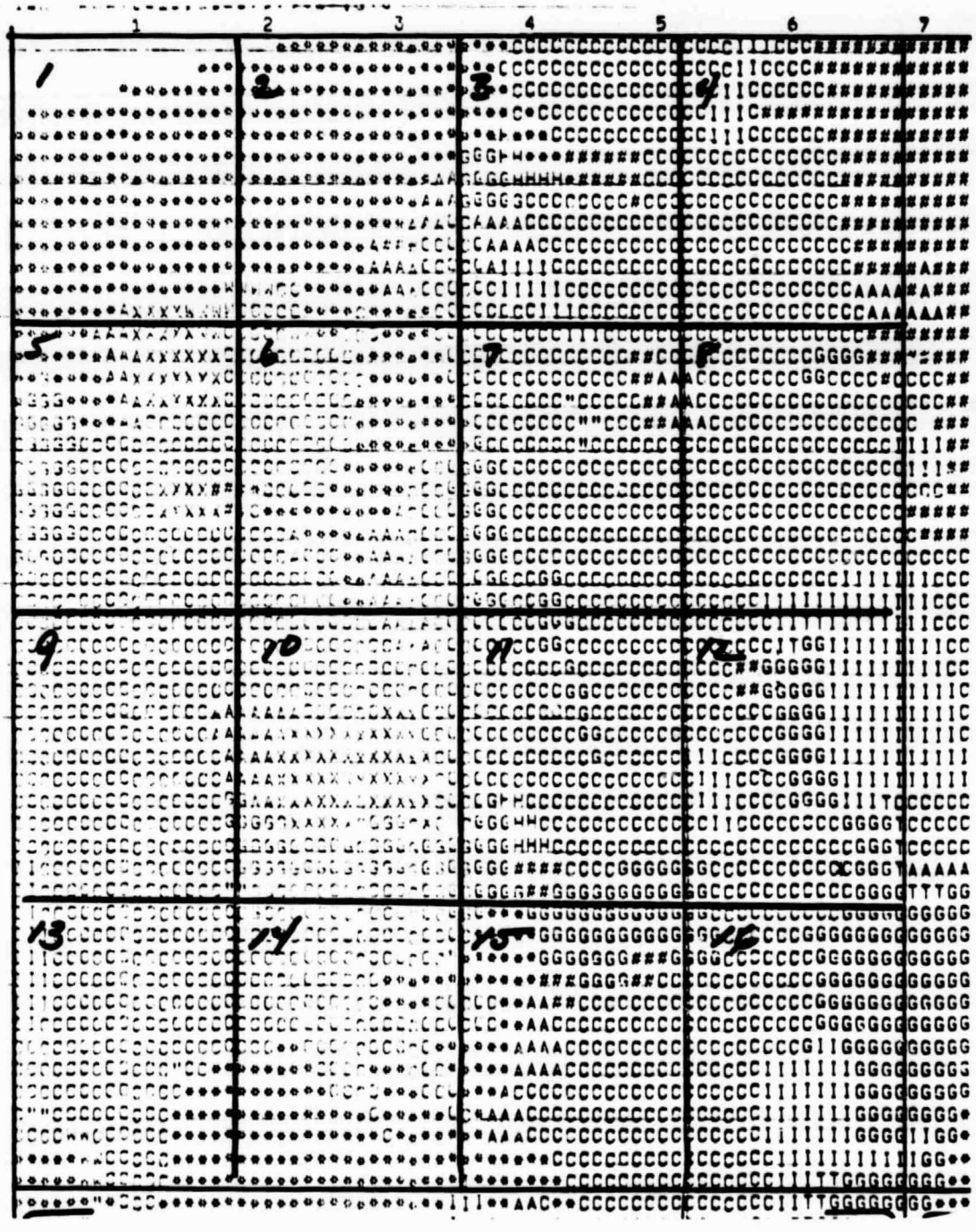
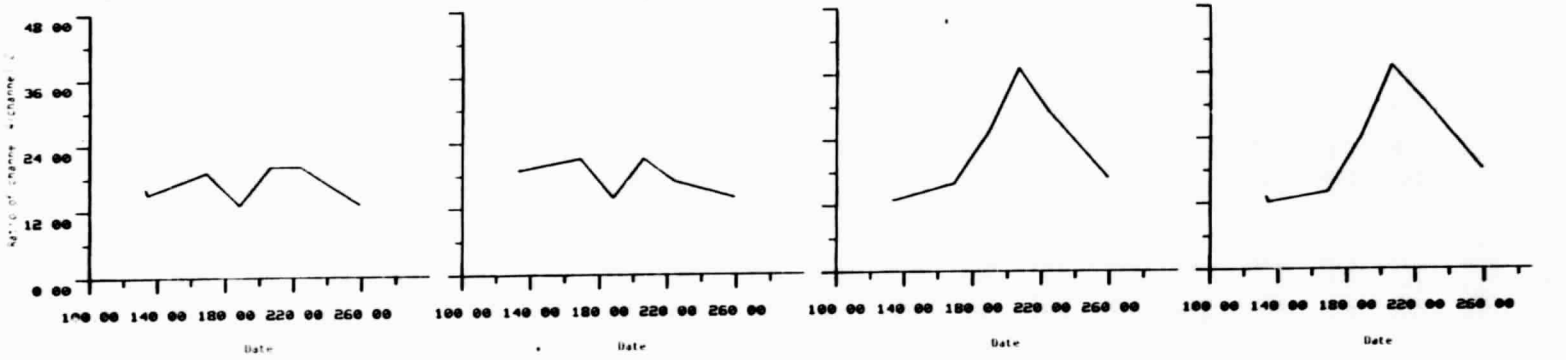
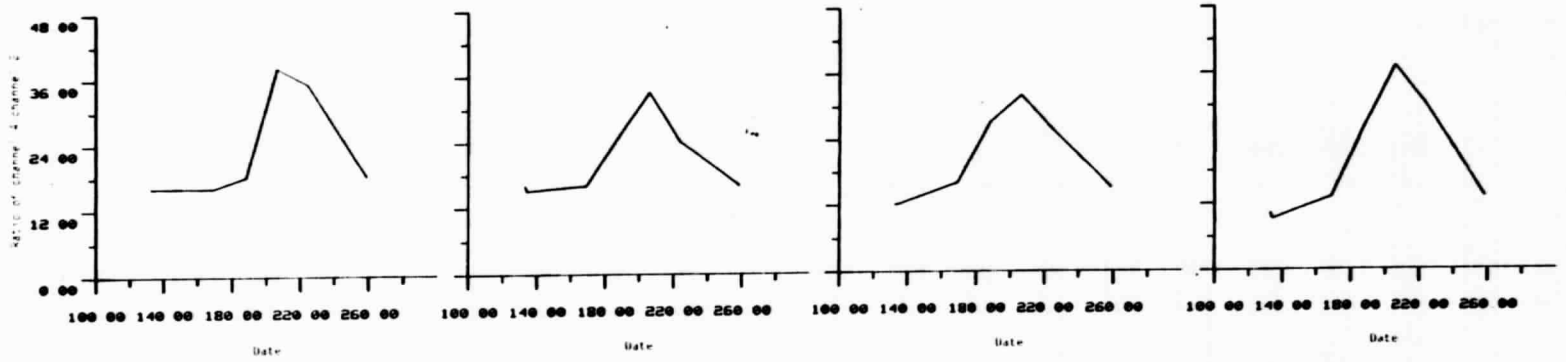


Figure 3.11-5.- The AA digitized ground truth map covering block position (001,001) in sample segment 1075.



(a) Pasture. (b) Pasture. (c) Corn. (d) Corn and homestead.



(e) Corn, grass, and soybeans. (f) Corn and pasture. (g) Corn. (h) Corn.

Figure 3.11-6.- The data profiles of the 16 cells in block position (001,001) in sample segment 1075.

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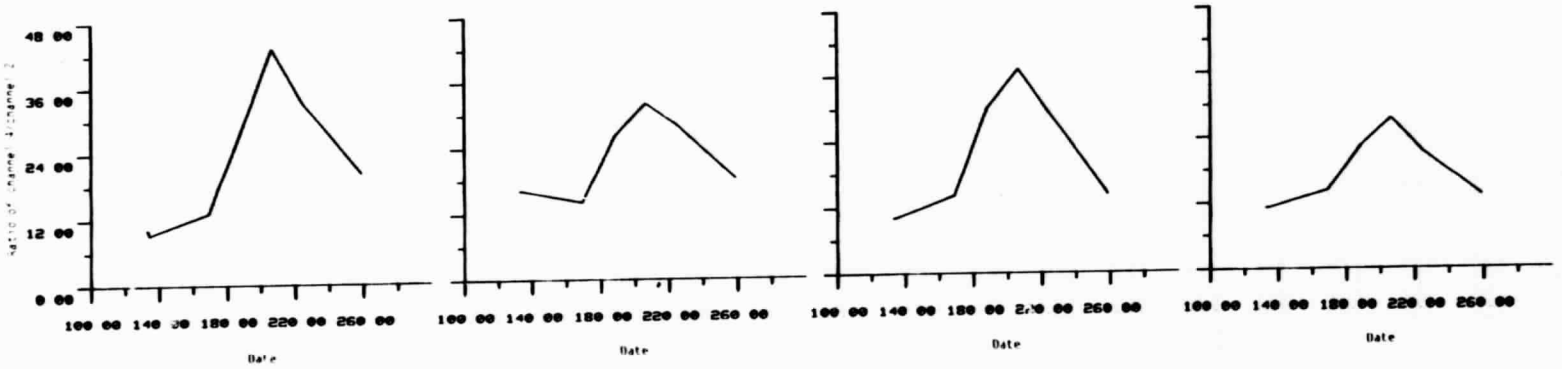
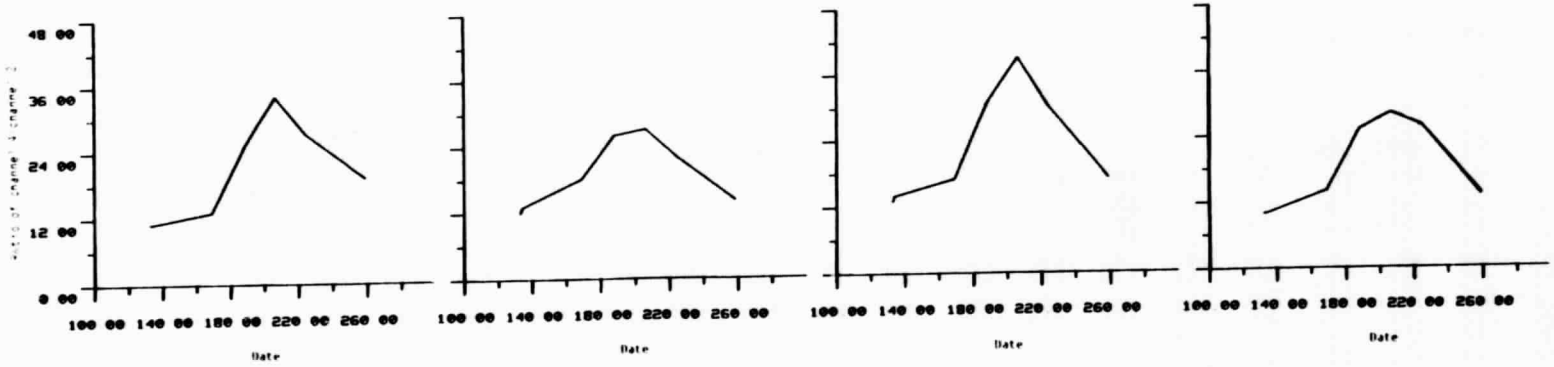


(i) Corn.

(j) Corn, soybeans, and grass.

(k) Corn and grass.

(l) Corn, grass, and idle land.



(m) Corn.

(n) Corn and pasture.

(o) Corn.

(p) Corn, grass, and idle land.

Figure 3.11-6.- Concluded.

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4. COMPARISON OF MULTIYEAR SIMULATED COVERAGE OVER CONSISTENT GEOGRAPHICAL AREAS

Segments used in the multiyear comparison have been discussed in detail in sections 2.6 and 3. Since some content varied from year to year, comparision at the LAC-scale level did not seem to be practical. Comparison of the GAC-scale simulation was done for:

Sample segment	Data
886	1978 and 1979
828	1978 and 1979
1725	1977 and 1978
1924	1977, 1978, and 1979

Block signatures of four blocks, registered to the same geographical area between the years, were illustrated and compared. Major scene component data graph profiles were illustrated and compared.

4.1 SAMPLE SEGMENT 886, POTTAWATOMIE COUNTY, IOWA

The following 1979 crop-year acquisitions from sample segment 886, Pottawatomie County, Iowa, were merged with the AA digitized ground truth.

Julian date	Landsat	Comments
79163	2	Pasture vigorous, ground plowed for summer crops
79172	3	Some summer crops emerging
79180	2	Summer crops vigorous
79207	3	Multiple popcorn clouds; crops vigorous
79243	3	Corn senescent
79252	2	Data drop for lines 42 and 92; corn harvest beginning
79261	3	

The 1979 crop-year data were misregistered with respect to the 1978 data. Hence, 1979 block position (001,001) was compared to 1978 block position

(008,001). This registration adjustment was defined using PFC products created from the image tapes. Comparison of the digitized ground truth maps would indicate a slight pixel adjustment and a line adjustment. Figure 4.1-1 illustrates the 1979 digitized ground truth for block position (001,001). Figure 4.1-2 illustrates the corresponding 1978 digitized ground truth for block position (008,001). Figure 4.1-3a is the data graph for crop-year 1979. The extremes evident for day 79252 may reflect the abnormal data that is evident in lines 42 and 92 on the image for this date, or they may reflect the apparent image/ground-truth misregistration. Figure 4.1-3b is the corresponding data graph for crop year 1978. Similarly, figure 4.1-4a is the data graph for block position (001,067) for 1979 data. Figure 4.1-4b is the data graph for the corresponding ground area in 1978. Figure 4.1-5a is the data graph for block position (053,001) in 1979. Figure 4.1-5b is the corresponding graph for 1978 data. Figure 4.1-6a is the data graph for block position (053,069) for 1979 data, and figure 4.1-6b is the corresponding area in 1978 data.

The scene content (taken from ground truth identification) changed from 1978 to 1979. Here is a comparison of pure Landsat pixels of the major scene content in block position (008,001) for 1978 and (001,001) for 1979.

Crop	1978	1979
Corn	1205	1240
Soybeans	534	427
Trees	74	151
Homestead	40	621

Ratio values indicate a marked change in value over vegetated areas.

Crop profiles for the 1979 crop-year, figures 4.1-7a through 4.1-7e, are presented for comparison with those in section 2.6-1 for corn, soybeans, summer crop, homestead, and trees.

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Figure 4.1-1.- The AA digitized ground truth map covering block position (001,001) in sample segment 886, 1979 crop year.

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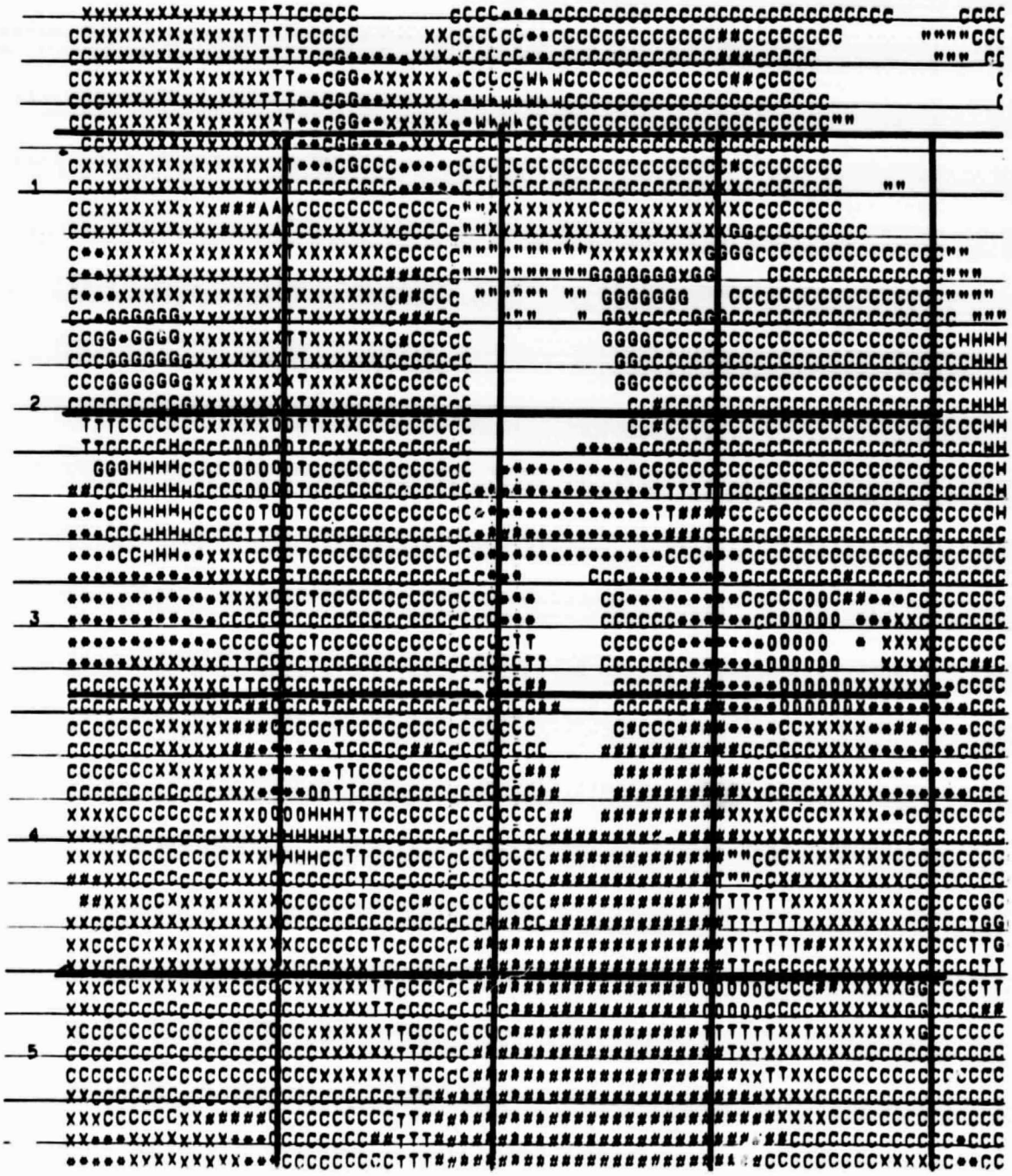

Figure 4.1-2.- The AA digitized ground truth map covering block position (008,001) in sample segment 886, 1978 crop year.

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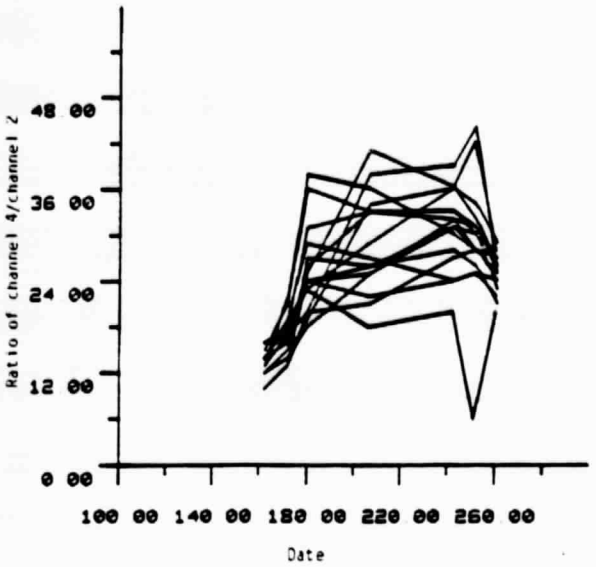

Figure 4.1-3a.- The 1979 data graph for block position (001,001).

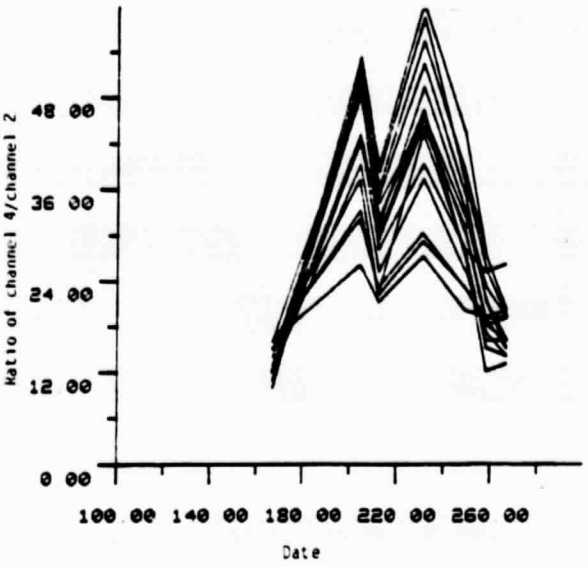

Figure 4.1-3b.- The 1978 data graph for block position (008,001).

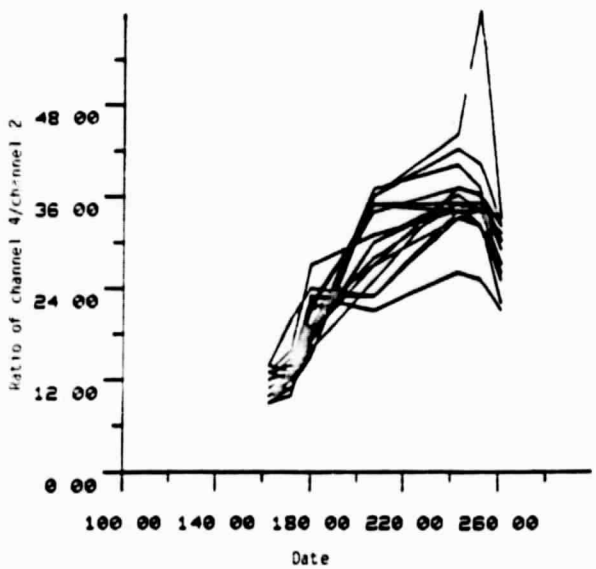

Figure 4.1-4a.- The 1979 data graph for block position (001,069).

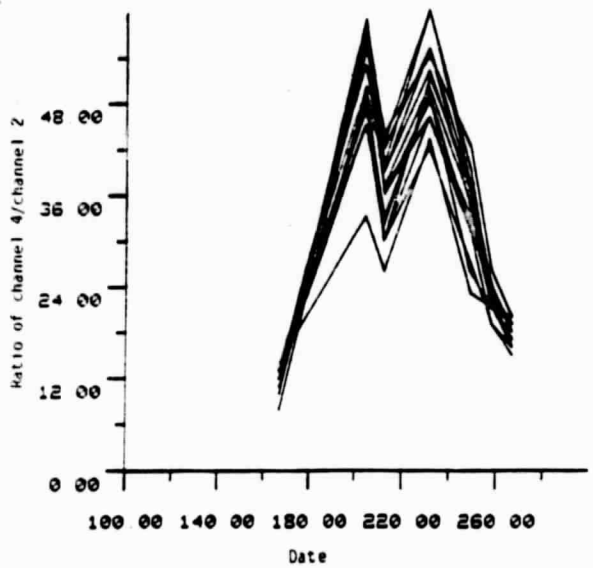

Figure 4.1-4b.- The 1978 data graph for block position (008,069).

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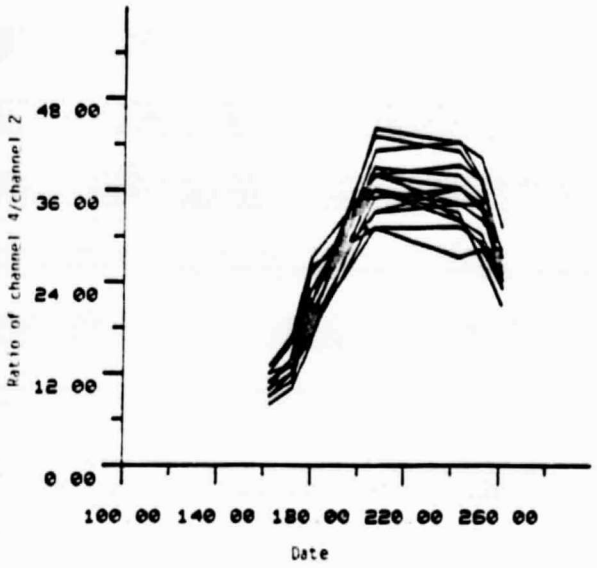

Figure 4.1-5a. - The 1979 data graph for block position (053,001).

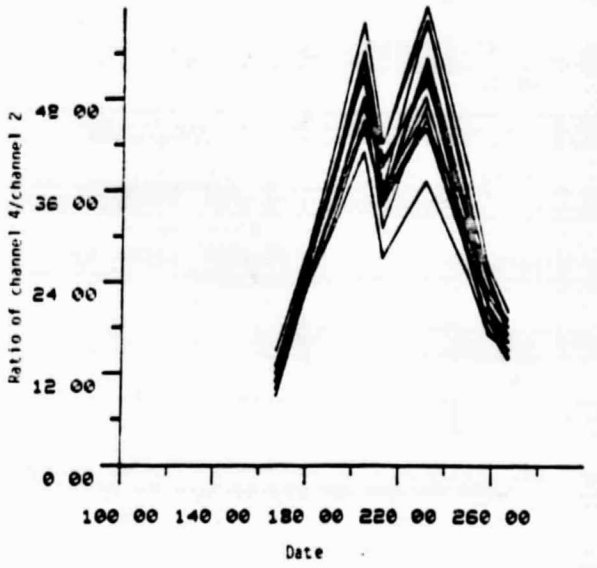

Figure 4.1-5b. - The 1978 data graph for block position (061,001).

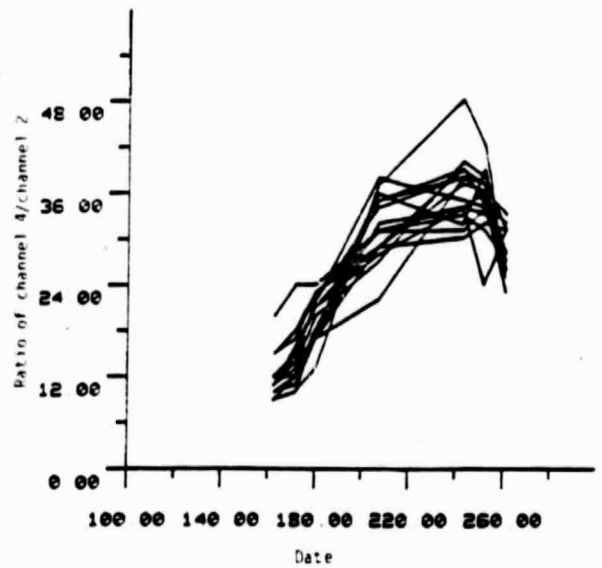

Figure 4.1-6a. - The 1979 data graph for block position (053,069).

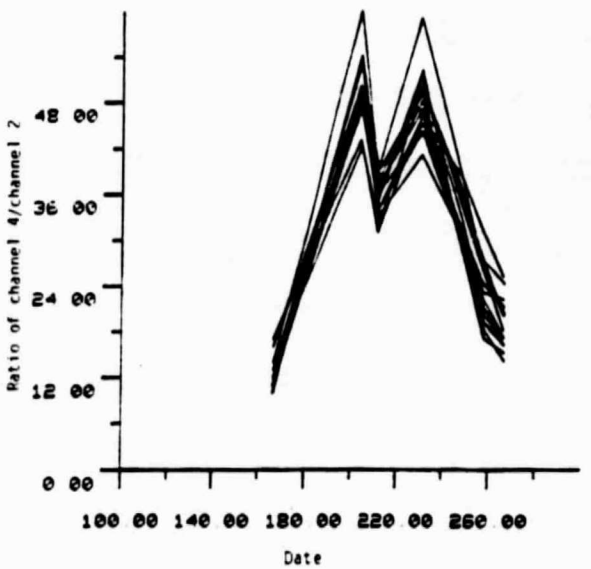

Figure 4.1-6b. - The 1978 data graph for block position (061,069).

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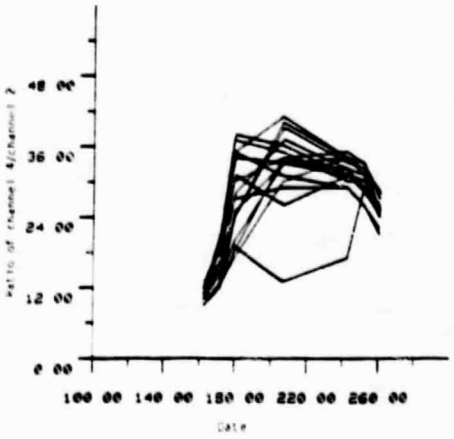

Figure 4.1-7a. - The 1979 corn crop profile.

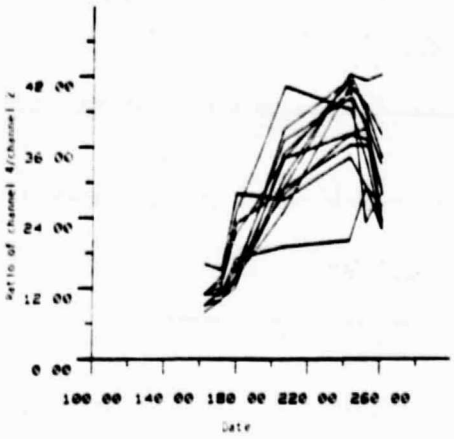

Figure 4.1-7b.- The 1979 soybean crop profile.

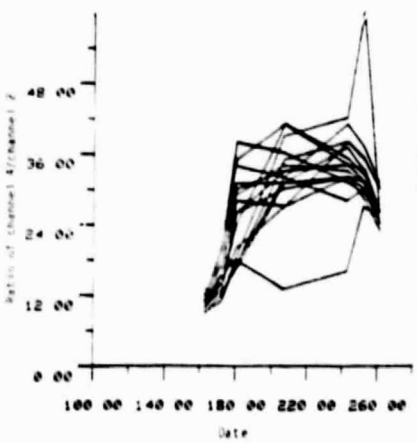

Figure 4.1-7c.- The 1979 summer crop profile.

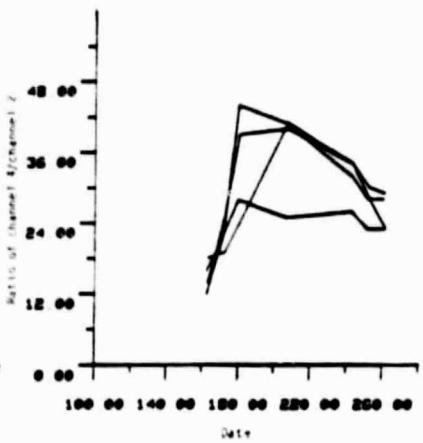

Figure 4.1-7d.- The 1979 tree profile.

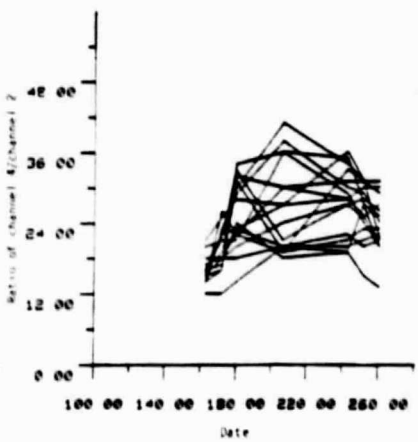

Figure 4.1-7e.- The 1979 homestead profile.

Composites of the mean values in a one-standard-deviation envelope are illustrated below for each crop for both years. Figure 4.1-8 shows corn for 1978 and 1979. Figure 4.1-9 shows soybeans for 1978 and 1979. Figure 4.1-10 illustrates the summer crop profile (corn and soybeans); figure 4.1-11 shows trees. The 1979 values are hatched.

4.2 SAMPLE SEGMENT 828, KANKAKEE COUNTY, ILLINOIS

The following 1979 crop-year acquisitions from sample segment 828, Kankakee County, Illinois, were merged with the AA digitized ground truth.

Julian date	Landsat	Comments
79167	3	Slight haze; emergence
79176	2	Some corn; very vigorous
79202	3	All vegetation in vigorous growth
79220	3	Corn senescent
79230	2	
79248	2	Small clouds; soybeans still vigorous
79265	2	Harvest in progress

As with sample segment 886, the 1979 crop-year acquisitions were misregistered with respect to the 1978 data. In the following illustrations, 1979 block position (001,001) corresponds to the area at (015,016) on 1978 images, and 1979 block position (001,069) corresponds to 1978 block position (068,085). Figure 4.2-1 illustrates the digitized ground truth for block position (001,001) for the 1979 crop year. Figure 4.2-2 depicts the ground truth for the corresponding area in 1978, which is block position (015,016). Figures 4.2-3 through 4.2-10 illustrate the data graphs for the corresponding blocks listed above. Below is the scene content taken from the ground truth identification of pure Landsat pixels in block positions (001,001) for 1979 and (015,016) for 1979.

Crop	1978	1979
Corn	1389	1814
Soybeans	919	945

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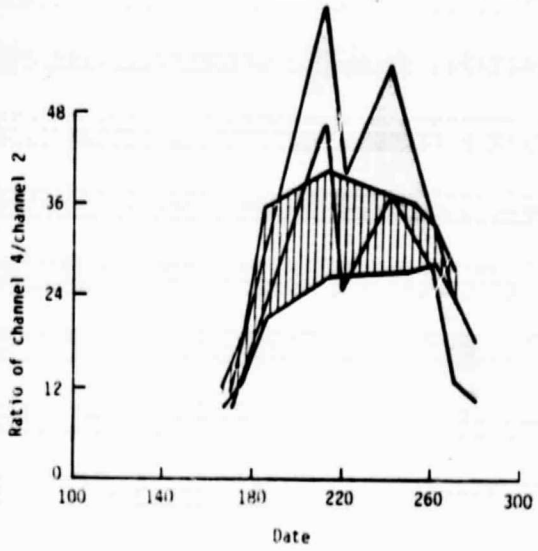

Figure 4.1-8. - Mean values of corn for 1978-79.

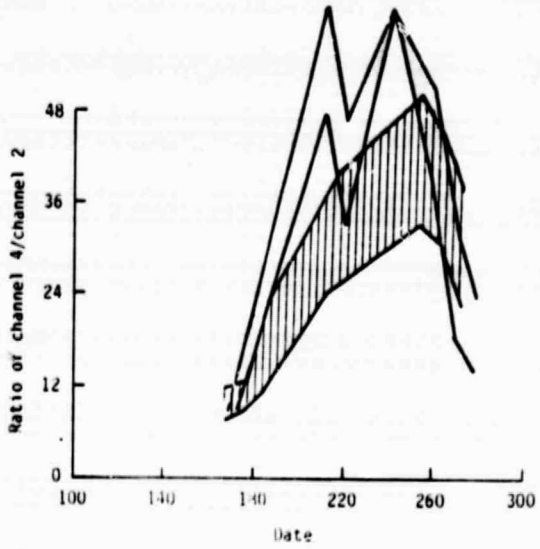

Figure 4.1-9. - Mean values of soybeans for 1978-79.

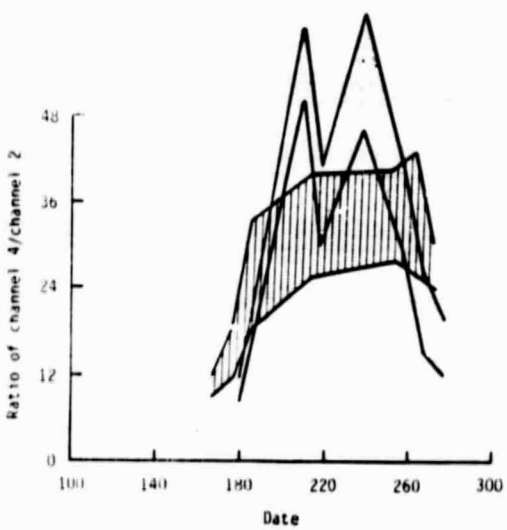

Figure 4.1-10. - Mean values of summer crops for 1978-79.

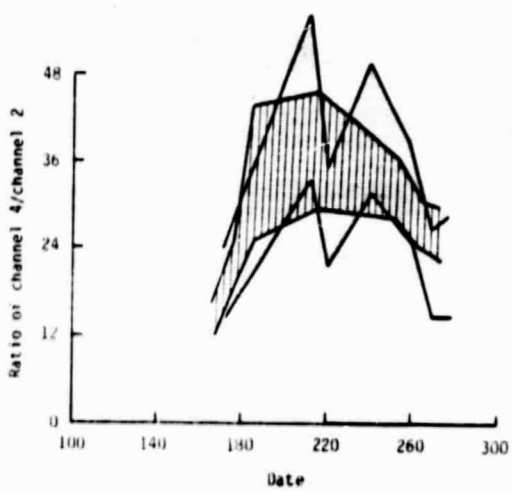

Figure 4.1-11.- Mean values of trees for 1978-79.

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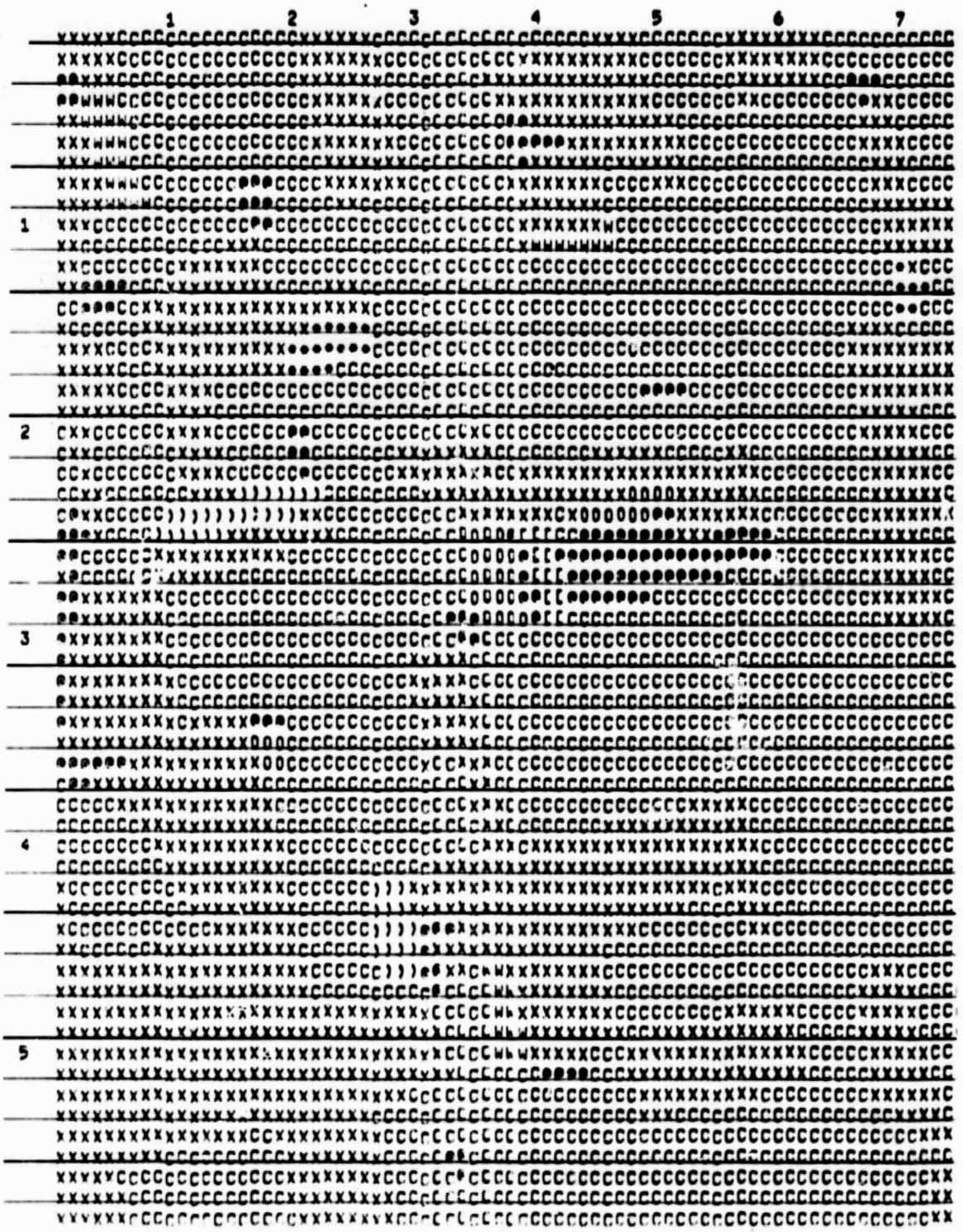

Figure 4.2-1.- The AA digitized ground truth map covering block position (001,001) in sample segment 828.

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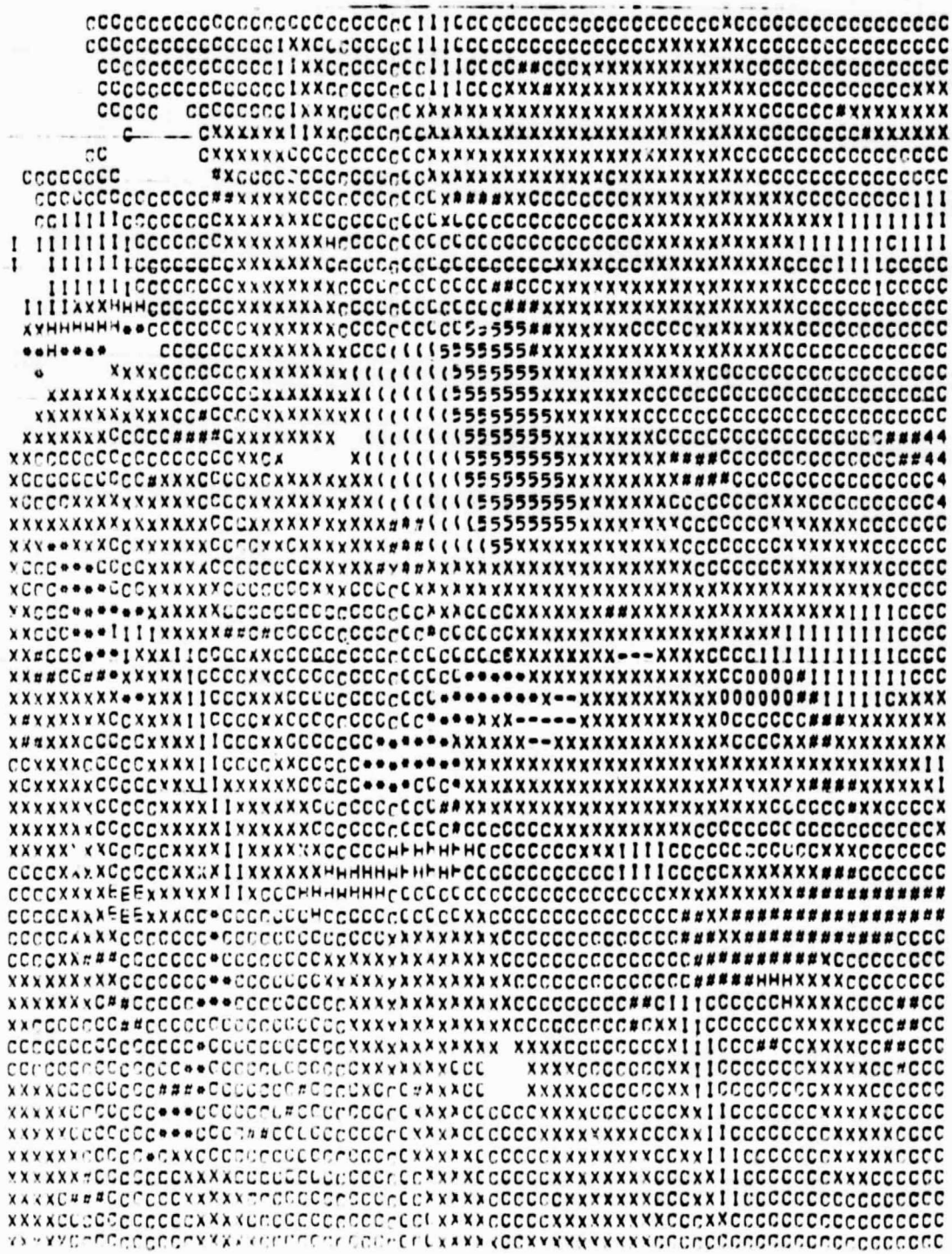

Figure 4.2-2.- The AA digitized ground truth map covering block position (015,016) in sample segment 828.

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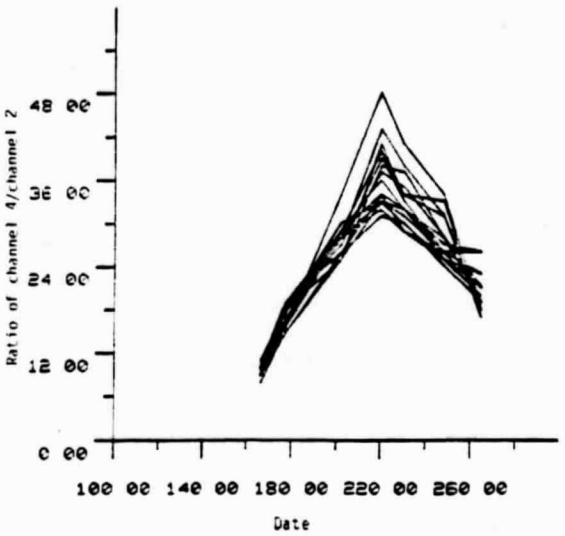

Figure 4.2-3a. - The 1979 data graph for block position (001,001).

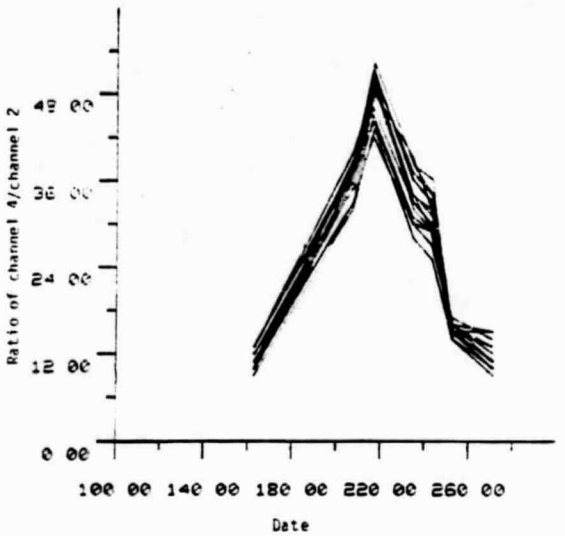

Figure 4.2-3b.- The 1978 data graph for block position (015,016).

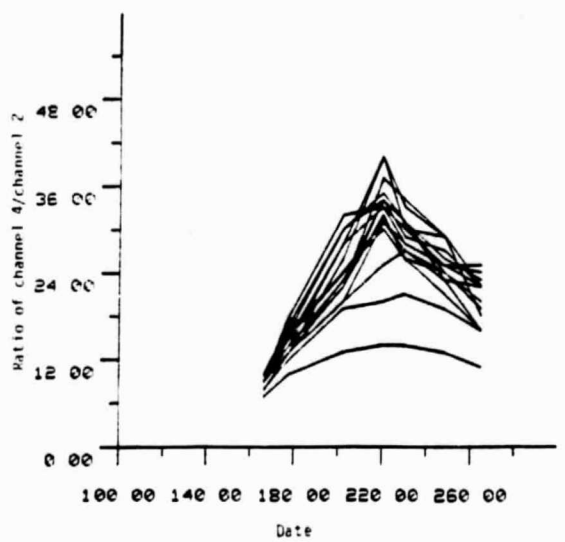

Figure 4.2-4a.- The 1979 data graph for block position (001,069).

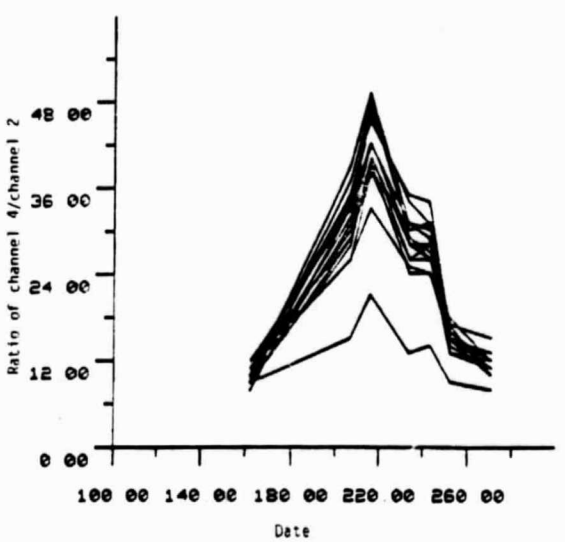

Figure 4.2-4b.- The 1978 data graph for block position (015,085).

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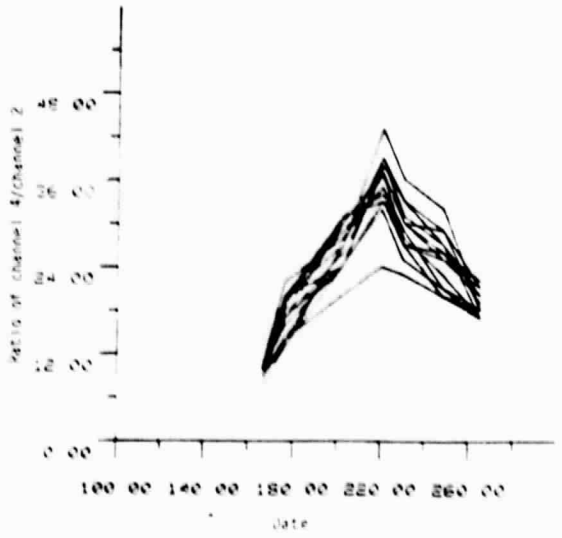

Figure 4.2-5a.- The 1979 data graph for block position (153,001).

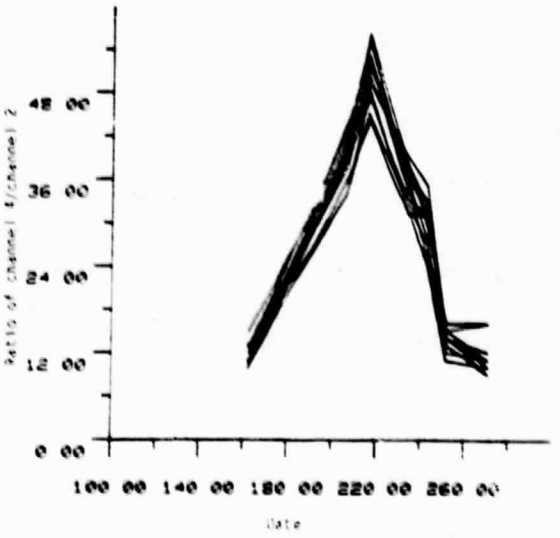

Figure 4.2-5b.- The 1978 data graph for block position (065,016).

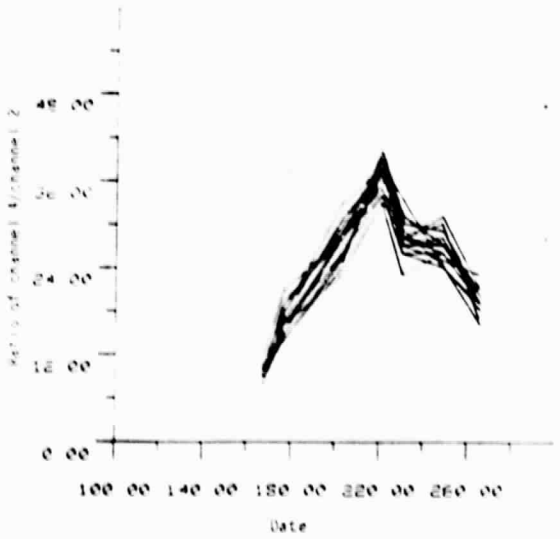

Figure 4.2-6a.- The 1979 data graph for block position (053,069).

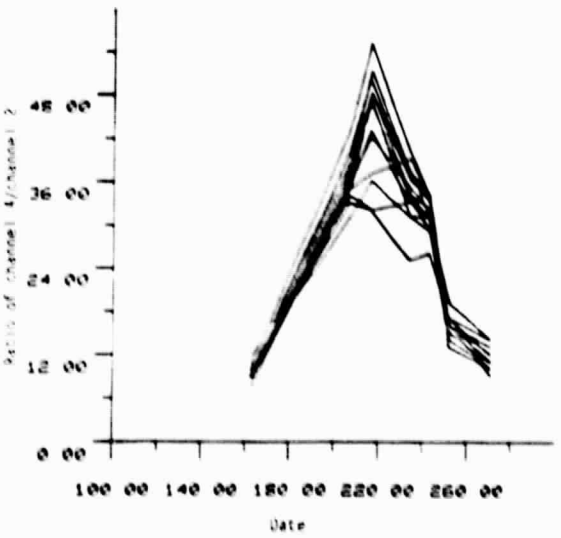

Figure 4.2-6b.- The 1978 data graph for block position (065,085).

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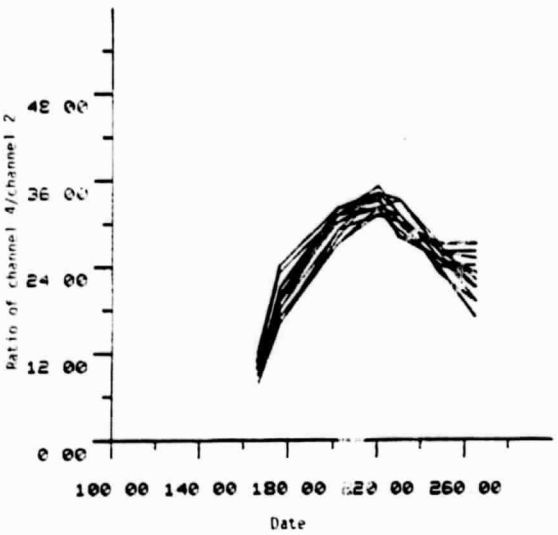

Figure 4.2-7a.- The 1979 corn crop profile.

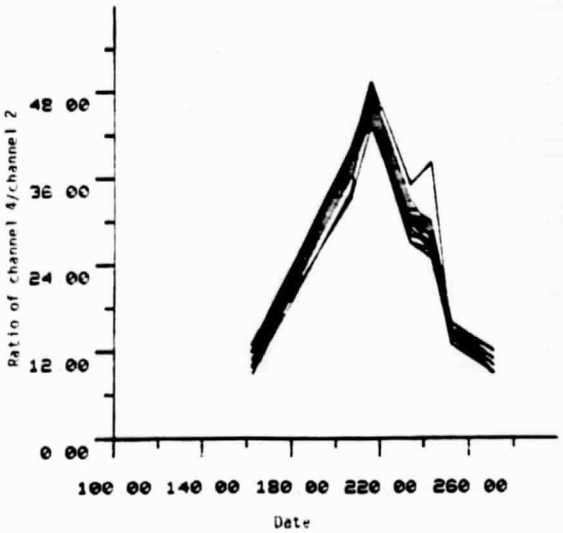

Figure 4.2-7b.- The 1978 corn crop profile.

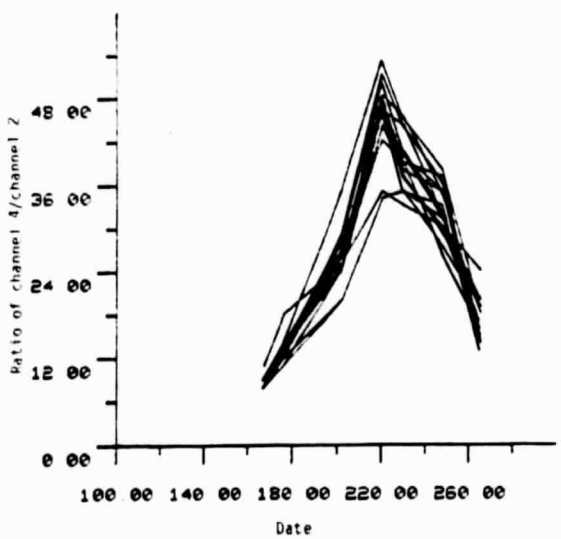

Figure 4.2-8a.- The 1979 soybean crop profile.

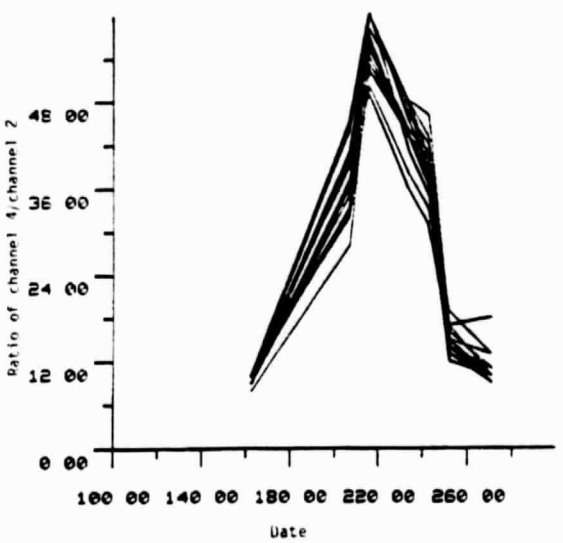

Figure 4.2-8b.- The 1978 soybean crop profile.

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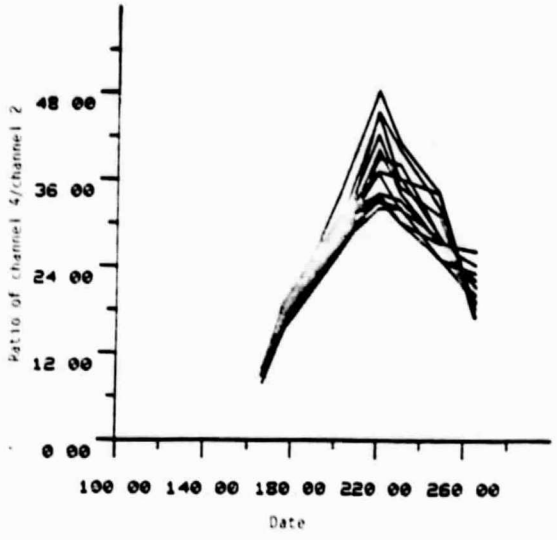

Figure 4.2-9a.- The 1979 summer crop profile.

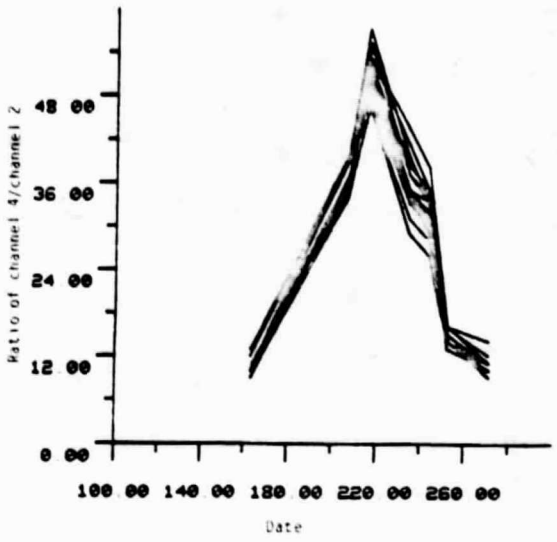

Figure 4.2-9b.- The 1978 summer crop profile.

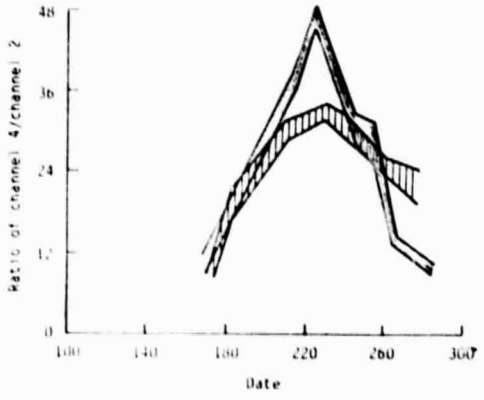

Figure 4.2-10.- Mean values of corn for 1978-79.

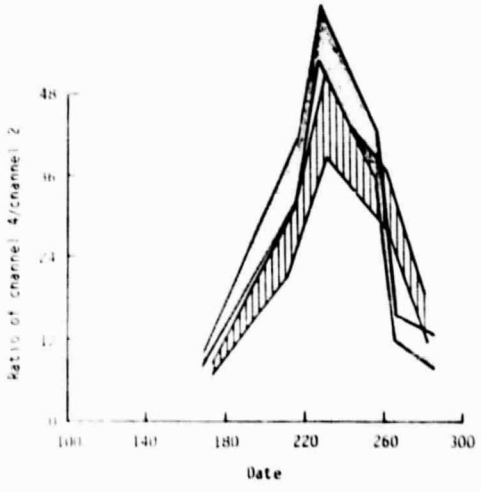

Figure 4.2-11.- Mean values of soybeans for 1978-79.

Ratioed values were higher in 1978 than in 1979, as they were in sample segment 886.

Crop profiles of corn (c) and soybeans (x) and a composite of these summer crops for 1978 and 1979 data are illustrated in figures 4.2-7a through 4.2-9b. Figures 4.2-7a and 4.2-7b show only corn and pure pixel input that is drawn from the same geographical area. Figures 4.2-8a and b show soybeans, and figures 4.2-9a and b illustrate the data graph of summer crops.

Composites of the mean values in a one standard deviation envelope are illustrated in figures 4.2-10 and 4.2-11. Figure 4.2-10 shows corn for 1978 and 1979, and figure 4.2-11 shows soybeans for 1978 and 1979; the 1979 values are hatched.

4.3 SAMPLE SEGMENT 1725, FLATHEAD COUNTY, MONTANA

The following 1977 crop-year acquisitions from sample segment 1725, Flathead County, Montana, were merged with the AA digitized ground truth.

Julian date	Landsat	Comments
77098	2	Trees, pasture emergent
77115	2	Alfalfa emergent
77152	2	Small grains emergent
77170	2	
77188	2	Small grains vigorous
77223	2	Alfalfa vigorous
77224	2	

Misregistration between years 1977 and 1978 was not a problem with this segment; hence, block positions below were in direct geographical correspondence. Figure 4.3-1 illustrates the ground truth for the 1977 AA digitized ground truth block position (001,001) data. Figures 4.3-2a and b through 4.3-5a and b illustrate data graphs for corresponding areas. The scene content taken from the ground truth is as follows:

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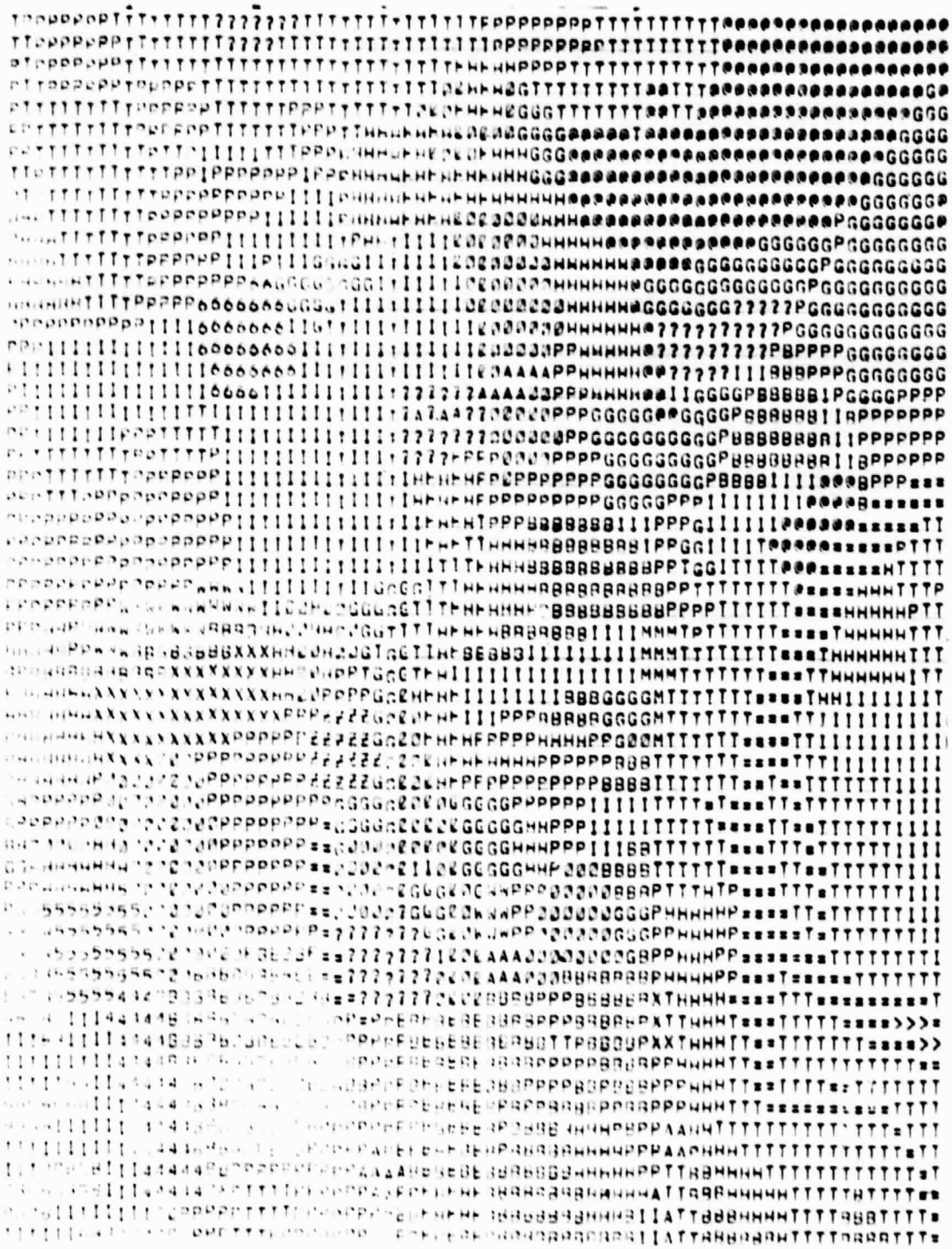

Figure 4.3-1.- The AA digitized ground truth map covering block position (001,001) in sample segment 1725.

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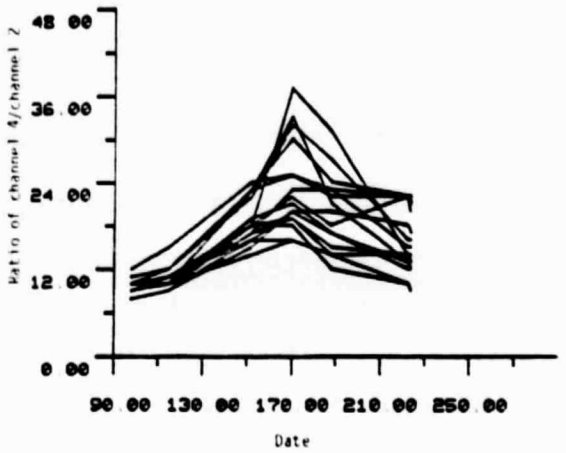

Figure 4.3-2a. - The 1977 data graph for block position (001,001).

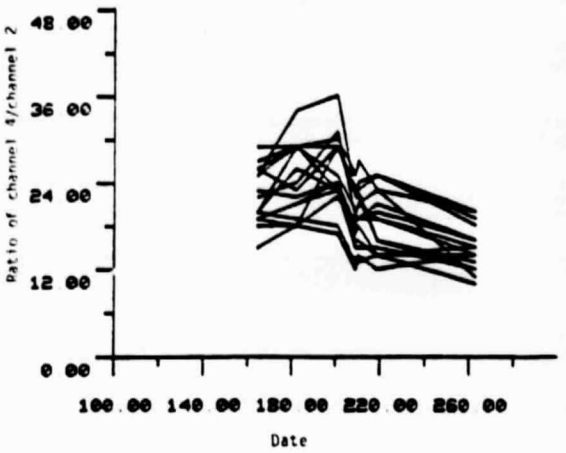

Figure 4.3-2b. - The 1978 data graph for block position (001,001).

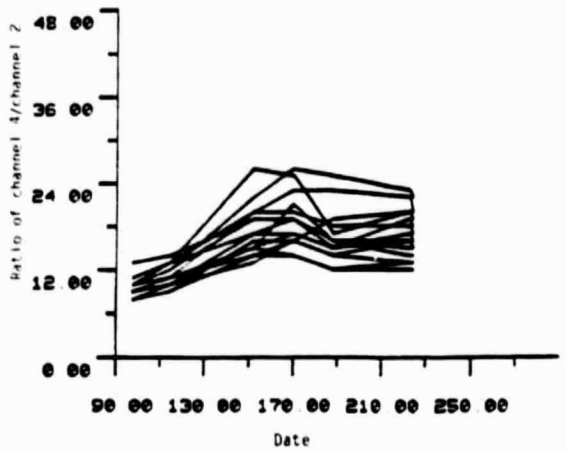

Figure 4.3-3a. - The 1977 data graph for block position (001,069).

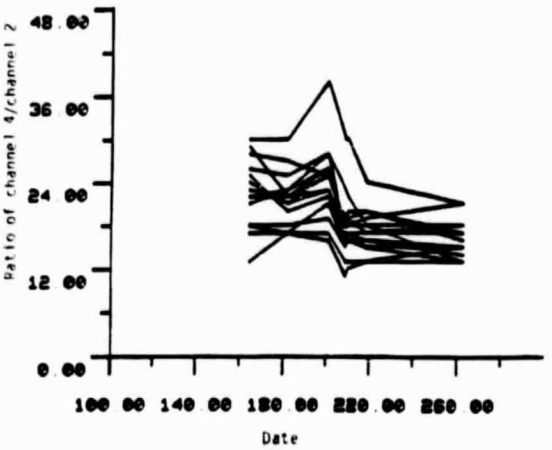

Figure 4.3-3b. - The 1978 data graph for block position (001,069).

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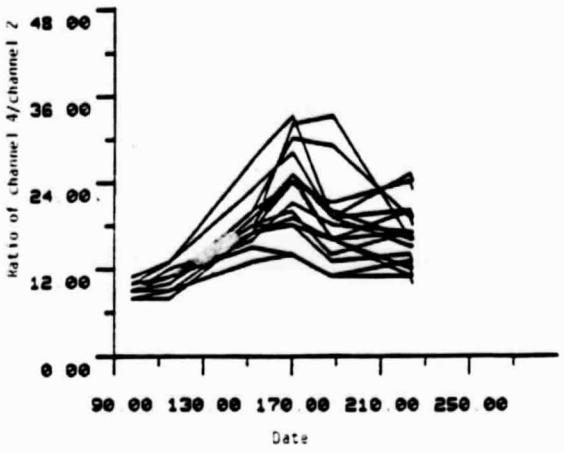

Figure 4.3-4a. - The 1977 data graph for block position (053,001).

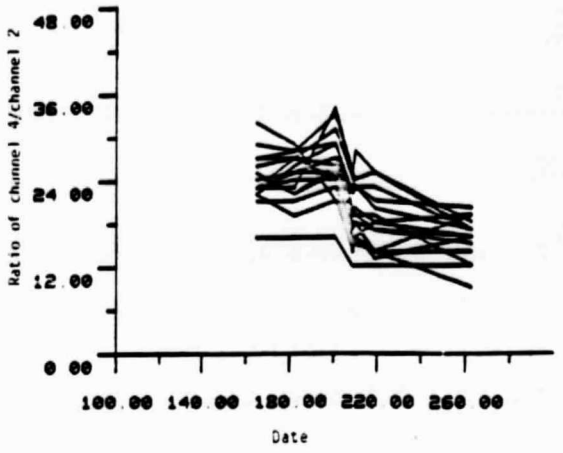

Figure 4.3-4b. - The 1978 data graph for block position (053,001).

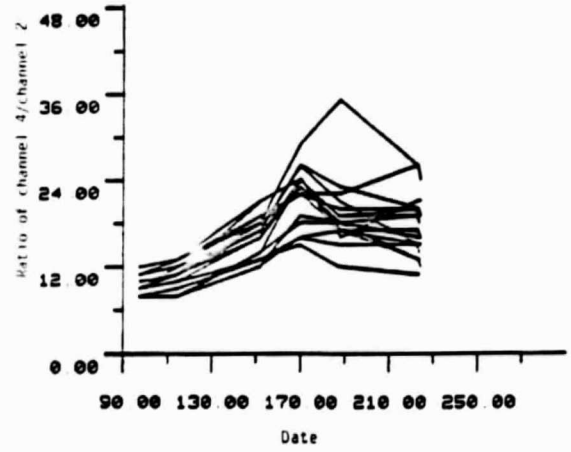

Figure 4.3-5a. - The 1977 data graph for block position (053,069).

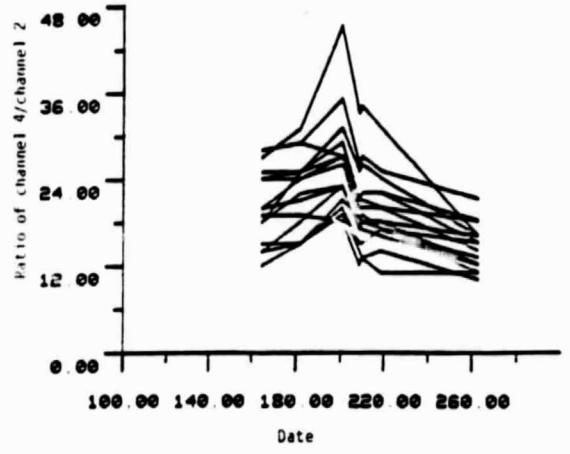

Figure 4.3-5b. - The 1978 data graph for block position (053,069).

Crop	Location	1977	1978
Spring grains	(001,001)	646	545
Pasture	(001,001)	395	291
Trees	(001,129)	1394	1639

Crop profiles of spring small grains (fig. 4.3-6a), pasture (fig. 4.3-6c), and trees (fig. 4.3-6b) are illustrated for comparison with figures 3.8-1a, b, and c.

Composites of the mean values in a one-standard-deviation envelope are illustrated in figures 4.3-7 through 4.3-9. Figure 4.3-7 shows spring grains (barley and wheat) for 1977 and 1978. Figure 4.3-8 shows pasture, and figure 4.3-9 shows trees. The 1979 graphs are horizontally hatched.

4.4 SAMPLE SEGMENT 1924, LA MOURE COUNTY, NORTH DAKOTA

The following 1977 crop-year acquisitions for sample segment 1924, La Moure County, North Dakota, were merged with the digitized ground truth for the year.

Julian date	Landsat	Comments
77122	2	Hay, alfalfa, and pasture emergent
77140	2	Pasture and hay areas vigorous; some grain emergence
77176	2	Vegetation vigorous
77194	2	One-half segment is deep cloud shadow
77230	2	Grains ripe and harvested

All acquisitions were from Landsat 2. Acquisitions were well distributed relative to the vegetation growth cycle even though there were only five acquisitions available; 1977 and 1978 acquisitions appeared to be registered.

The following 1979 crop-year acquisitions were merged with the 1979 digitized ground truth.

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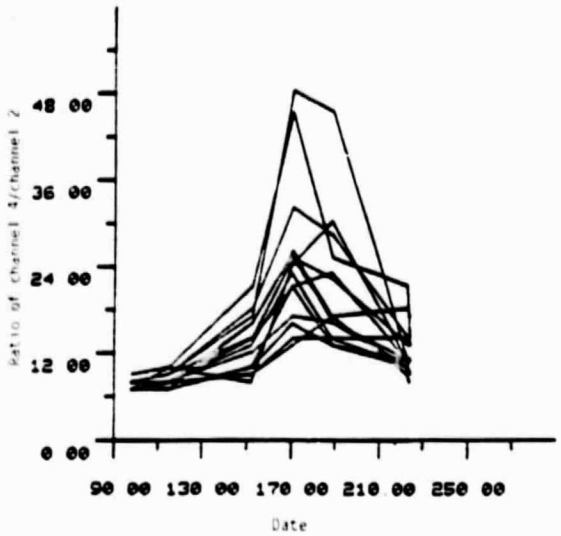

Figure 4.3-6a. - The 1977 small grains profile.

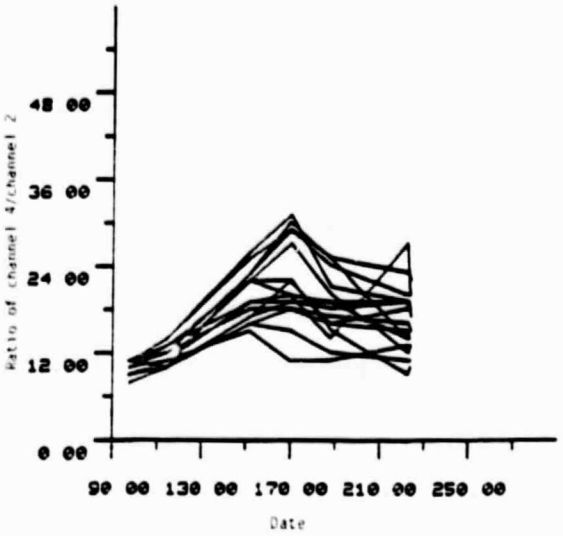

Figure 4.3-6c. - The 1977 pasture profile.

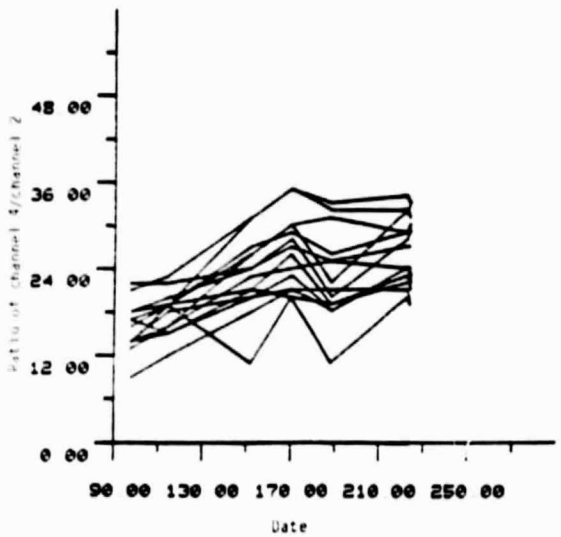

Figure 4.3-6b. - The 1977 trees profile.

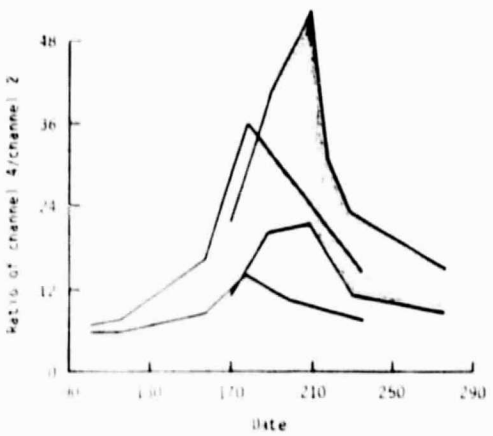

Figure 4.3-7. - Mean values of spring small grains for 1977-78.

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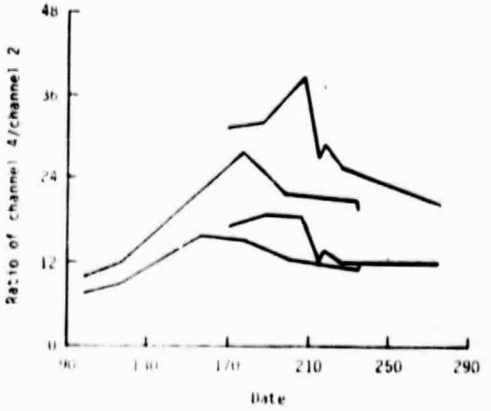

Figure 4.3-8.- Mean values of pasture for 1977-78.

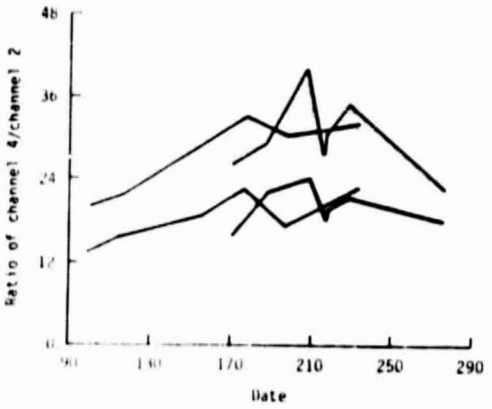

Figure 4.3-9.- Mean values of trees for 1977-78.

Julian date	Landsat	Comment
79112	2	Pasture and hay barely emergent
79148	2	Pasture and hay vigorous
79167	2	Hay vigorous; small grains emergent
79184	2	Scattered clouds; grains vigorous
79220	2	Grains senescent
79230	3	Grains ripe and harvested
79274	2	

Figure 4.4-1 shows the AA digitized ground truth for block position (001,001) for 1979. Figure 4.4-2 shows the AA digitized ground truth for the corresponding area in 1978, block position (006,001). Figure 4.4-3 shows the AA digitized ground truth for block position (006,001) for 1977. In figure 4.4-4a, block position (001,001) for 1979 corresponds to block position (006,001) for the 1978 and 1977 images (figs. 4.4-4b and 4.4-4c). Figures 4.4-5a through 4.4-7c illustrate the data graphs for the corresponding blocks remaining. In figure 4.4-5a, block position (001,069) for 1979 corresponds to block position (006,069) for 1978 and 1977 images (figs. 4.4-5b and 4.4-5c). In figure 4.4-6a, block position (053,001) for 1979 corresponds to block position (059,069) for 1978 and 1977 images (figs. 4.4-6b and 4.4-6c).

Scene content variation taken from the ground truth identification of the pure Landsat pixels input to the graphs are below:

Crop	1977	1978	1979
Spring wheat	1052	827	900
Pasture	728	258	517
Safflower and sunflower	39	235	628
Idle land	238	362	239

Profiles of spring wheat, pasture, safflower and sunflower, and idle land are presented in figures 4.4-8a through 4.4-11c. These profiles were generated from comparable geographic areas across the years. Figures 4.4-8(a) through

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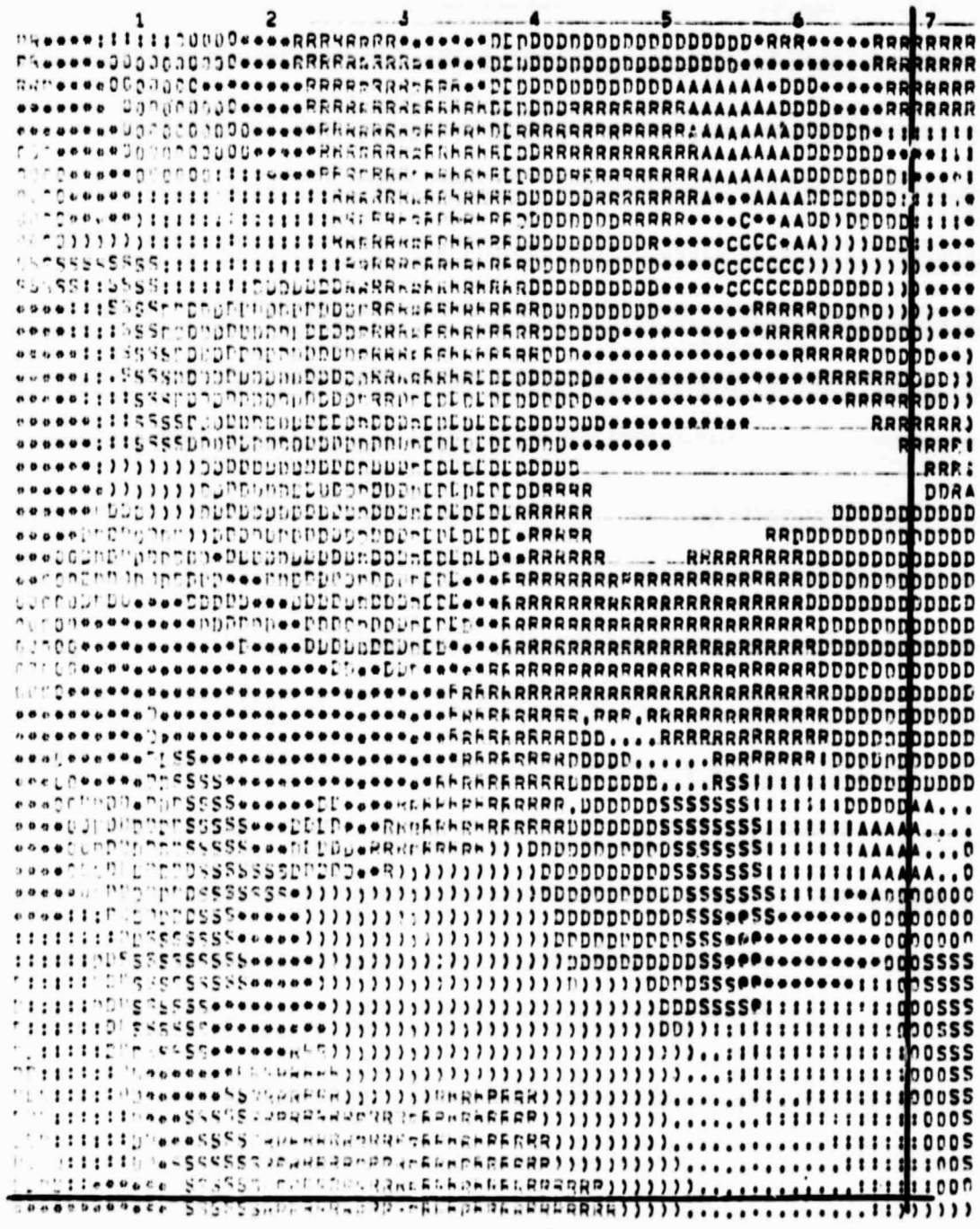

Figure 4.4-1.- The 1979 AA digitized ground truth map covering block position (001,001) in sample segment 1924.

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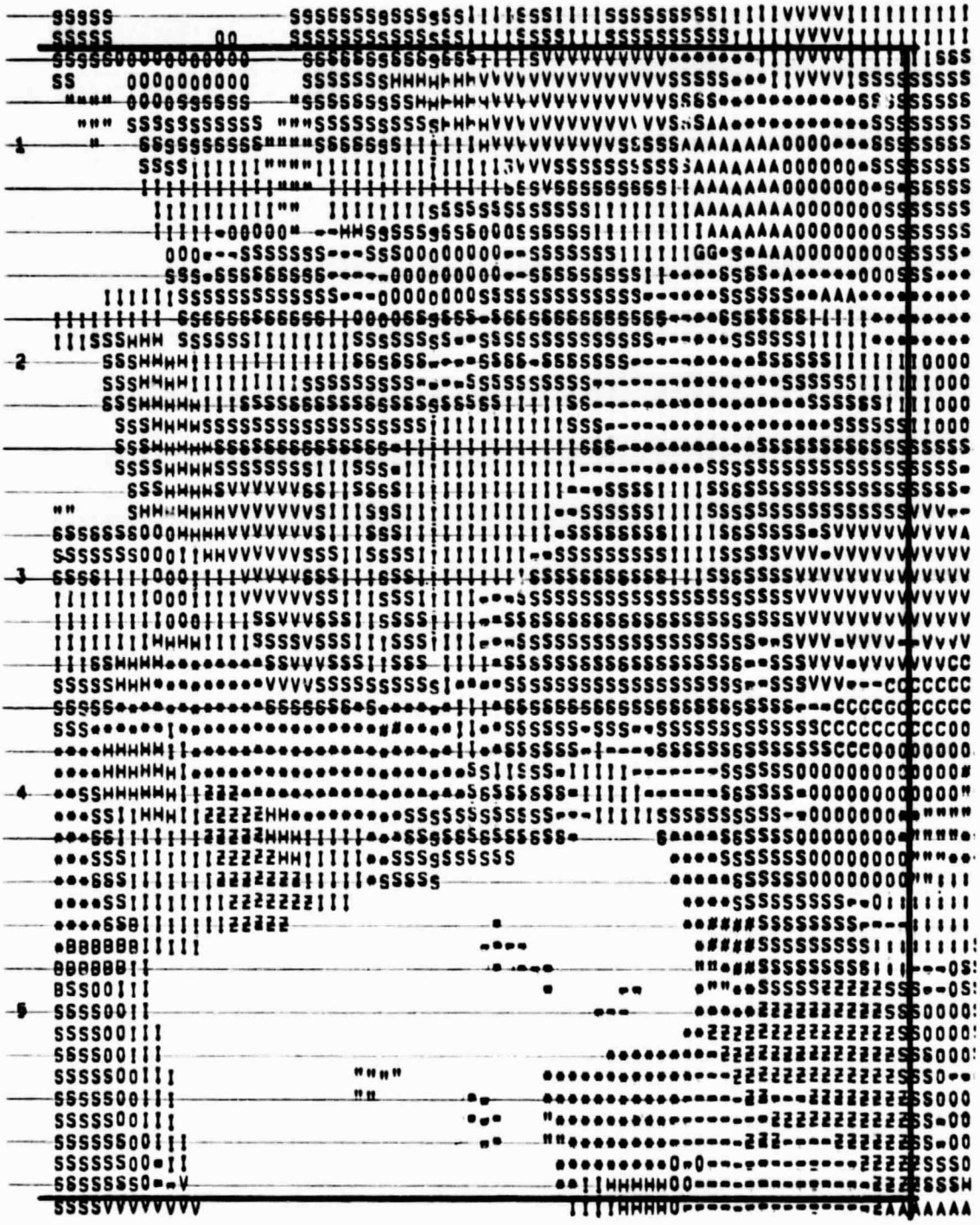

Figure 4.4-2.- The 1978 AA digitized ground truth map covering block position (006,001) in sample segment 1924.

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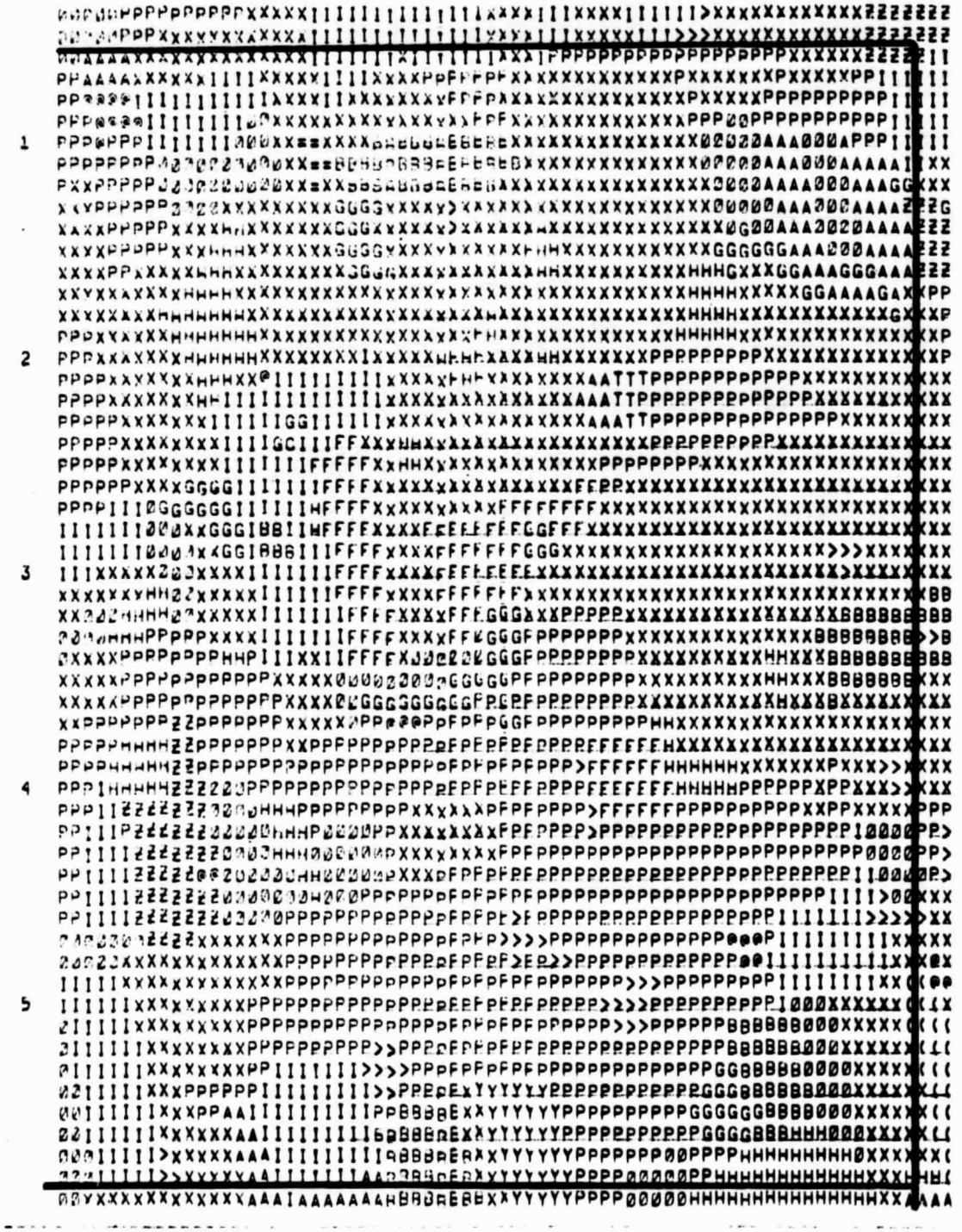

Figure 4.4-3.- The 1977 AA digitized ground truth map covering block position (006,001) in sample segment 1924.

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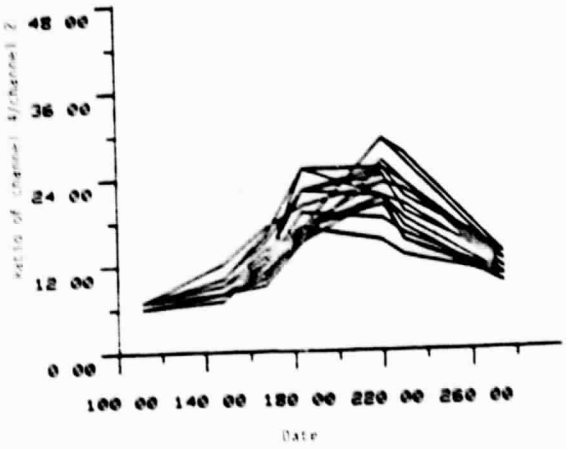

Figure 4.4-4a. - The 1979 data graph for block position (001,001).

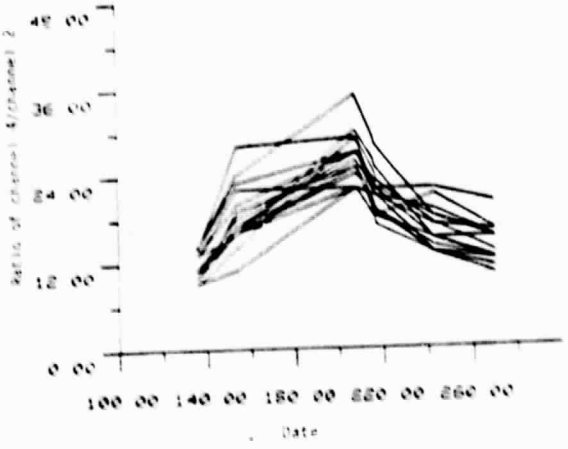

Figure 4.4-4b. - The 1978 data graph for block position (006,001).

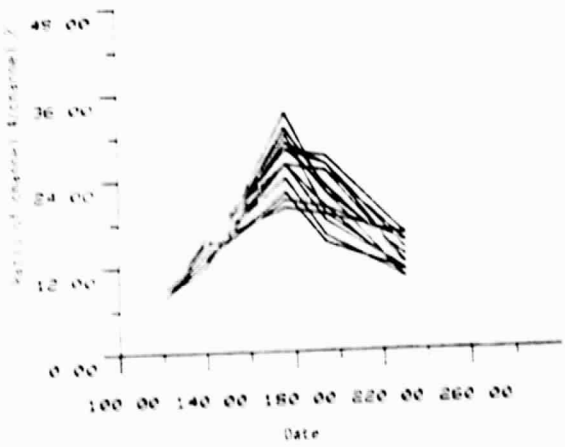

Figure 4.4-4c. - The 1977 data graph for block position (006,001).

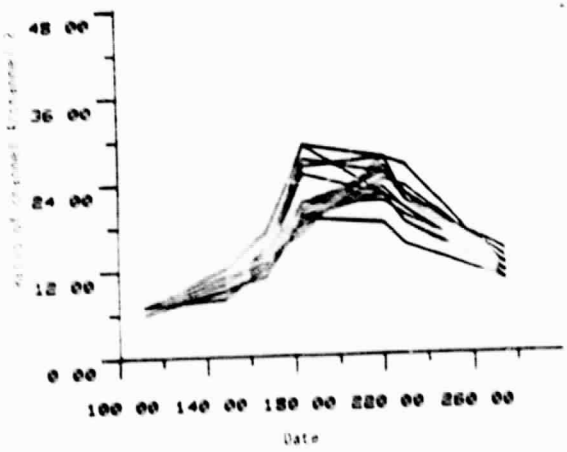

Figure 4.4-5a. - The 1979 data graph for block position (001,069).

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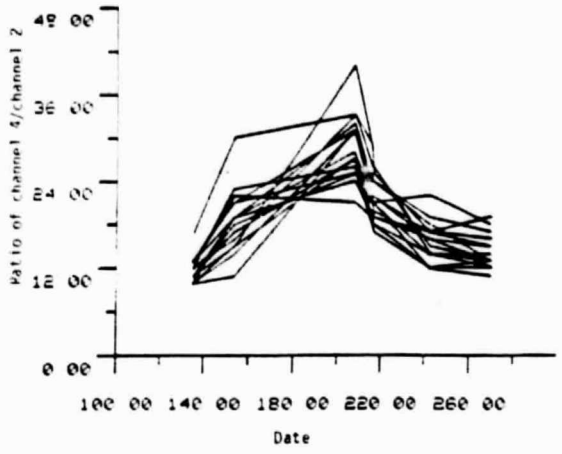

Figure 4.4-5b. - The 1978 data graph for block position (006,069).

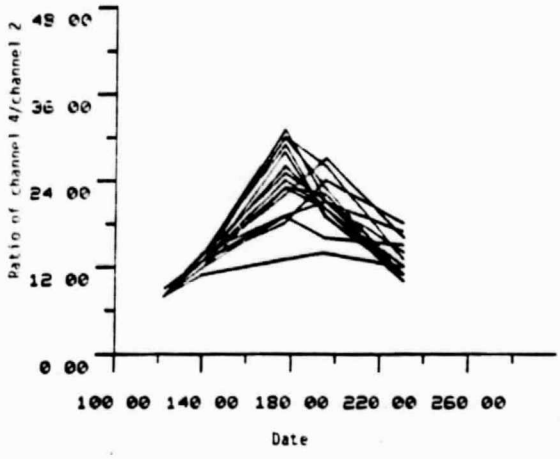

Figure 4.4-5c. - The 1977 data graph for block position (006,069).

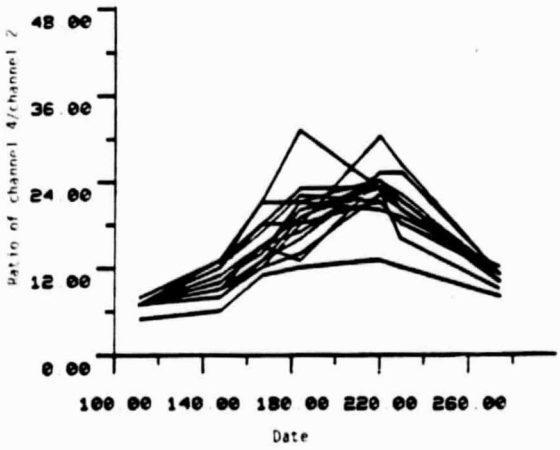

Figure 4.4-6a. - The 1979 data graph for block position (053,001).

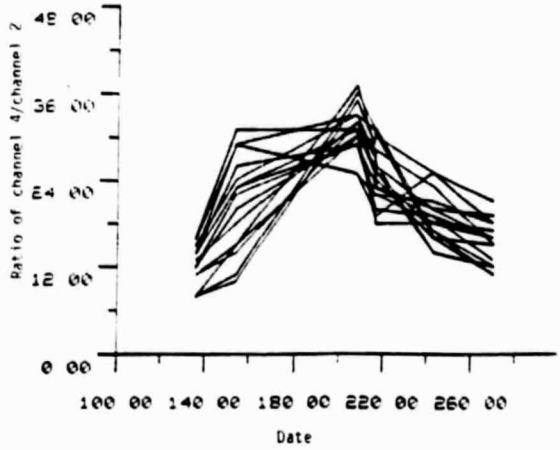

Figure 4.4-6b. - The 1978 data graph for block position (059,001).

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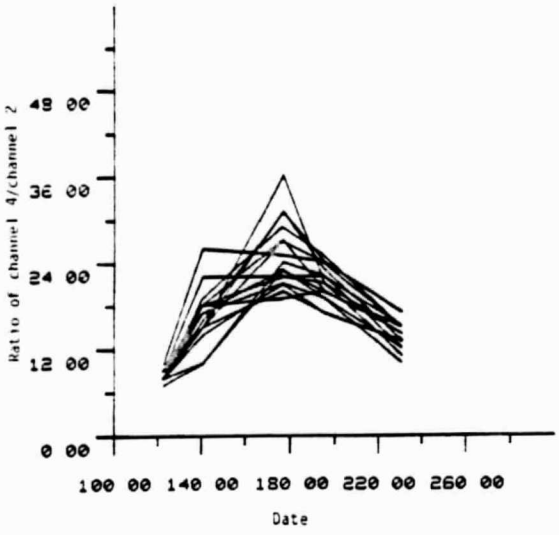


Figure 4.4-6c. - The 1977 data graph for block position (059,001).

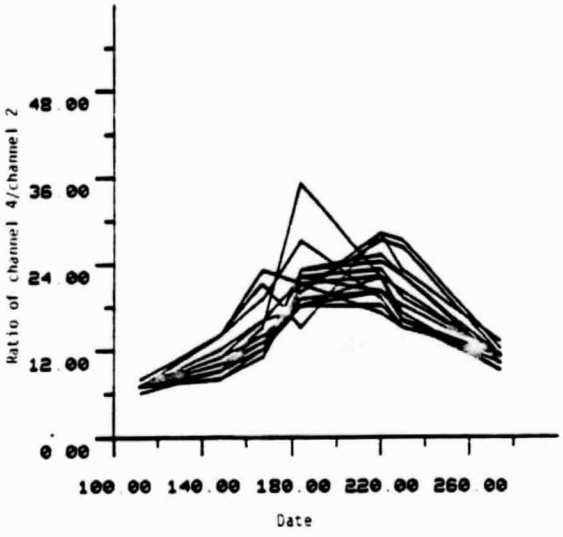


Figure 4.4-7a. - The 1979 data graph for block position (053,069).

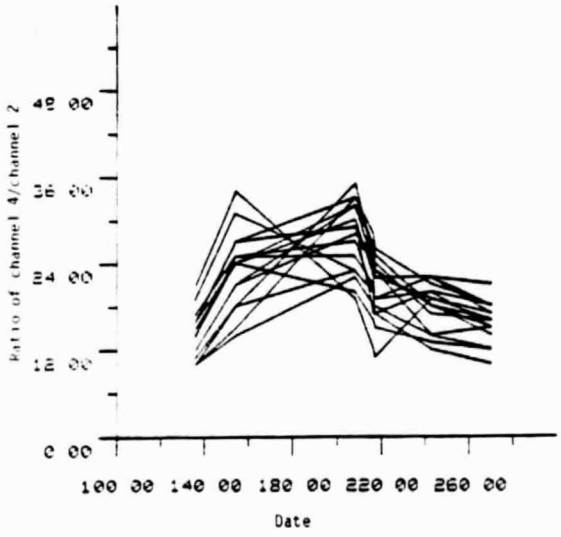


Figure 4.4-7b. - The 1978 data graph for block position (059,069).

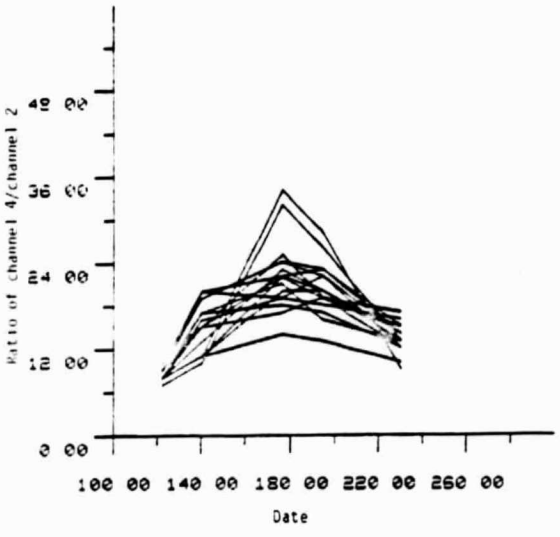
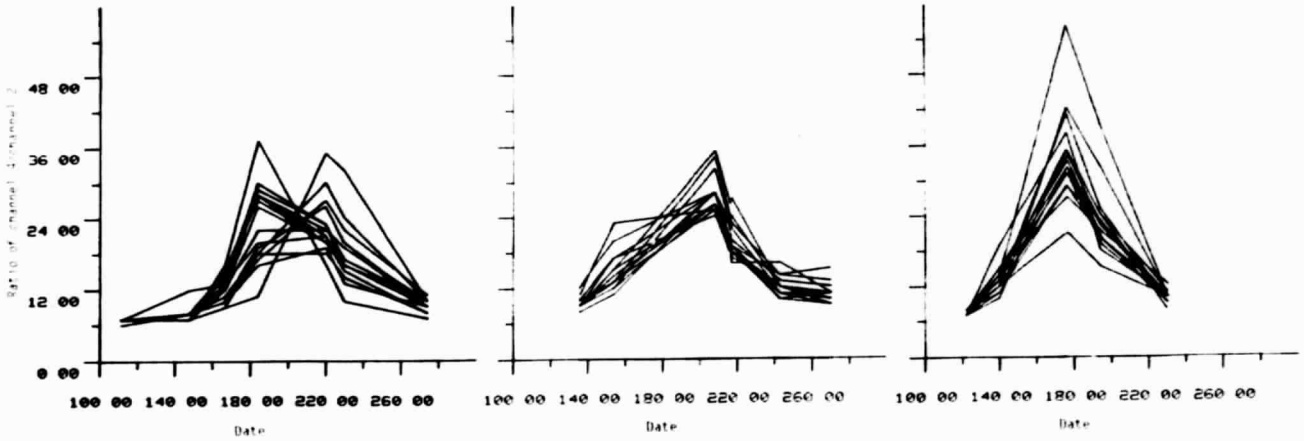
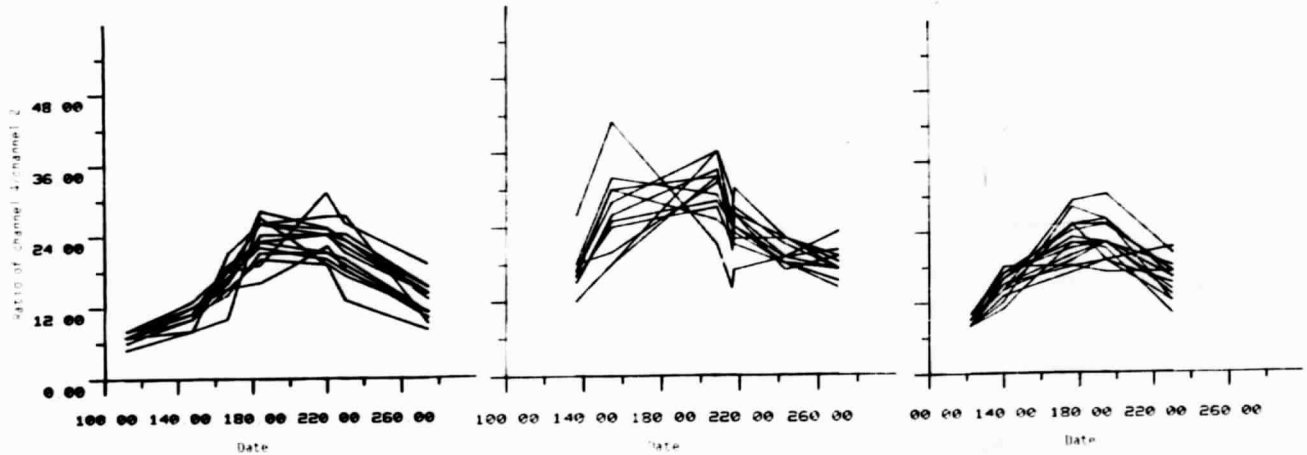


Figure 4.4-7c. - The 1977 data graph for block position (059,069).



(a) 1979. (b) 1978. (c) 1977.

Figure 4.4-8.- Profiles of 1979, 1978, and 1977 spring wheat.



(a) 1979. (b) 1978. (c) 1977.

Figure 4.4-9.- Profiles of 1979, 1978, and 1977 pasture.

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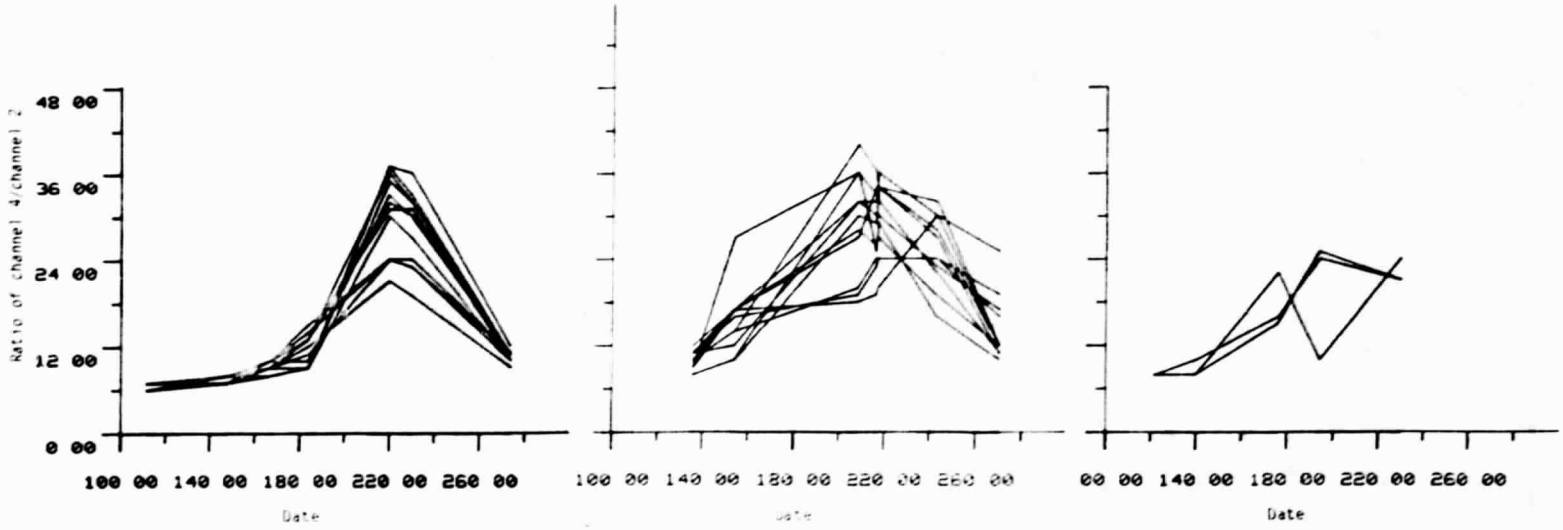
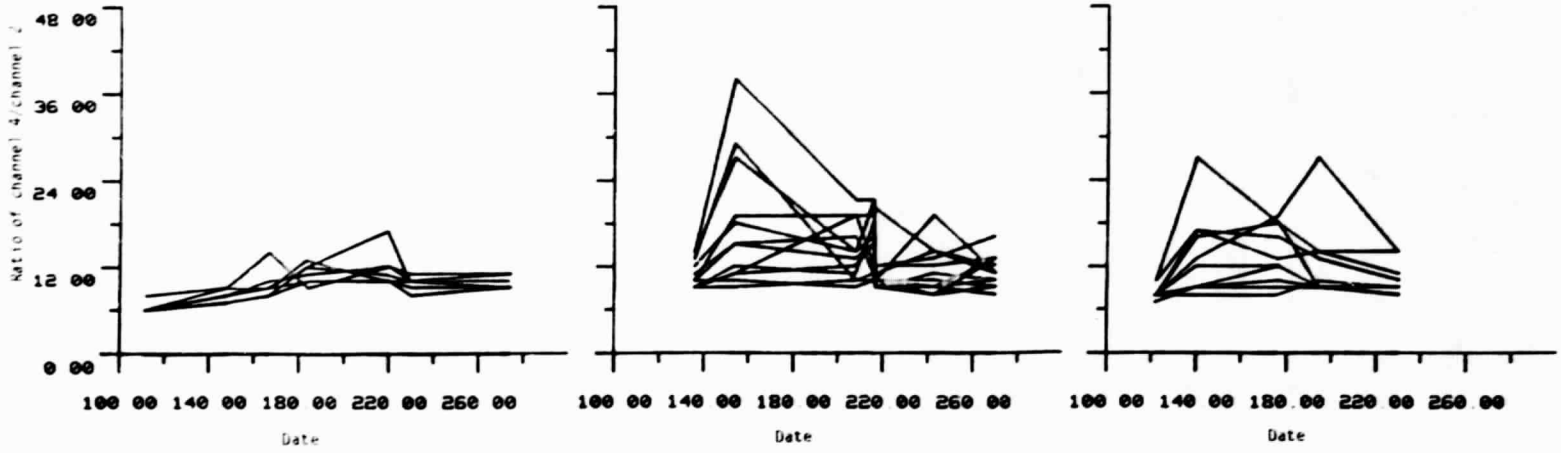


(a) 1979. (b) 1978. (c) 1977.

Figure 4.4-10.- Profiles of 1979, 1978, and 1977 safflowers and sunflowers.



(a) 1979. (b) 1978. (c) 1977.

Figure 4.4-11.- Profiles of 1979, 1978, and 1977 idle land.

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(c) illustrate spring wheat, figures 4.4-9(a) through (c) illustrate pasture figures 4.4-10(a) through (c) illustrate safflower and sunflower, and figures 4.4-11(a) through (c) illustrate idle land.

Composites of the mean values in a one-standard-deviation envelope are illustrated in figures 4.4-12 through 4.4-15 for each scene component; 1979 data are hatched vertically, 1978 data are blank, and 1977 data are hatched horizontally. Figure 4.4-12 shows spring wheat, figure 4.4-13 shows pasture, figure 4.4-14 shows safflower and sunflower, and figure 4.4-15 shows idle land.

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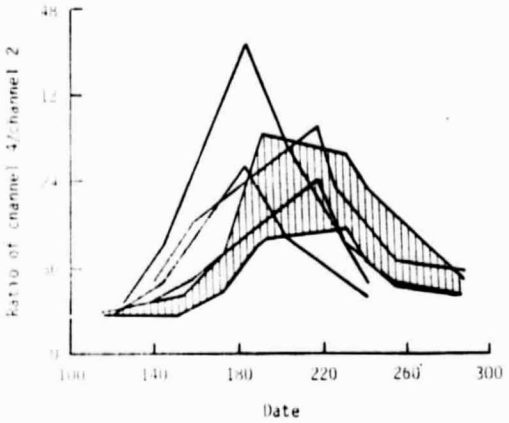

Figure 4.4-12.- Mean values of spring wheat for 1977-79.

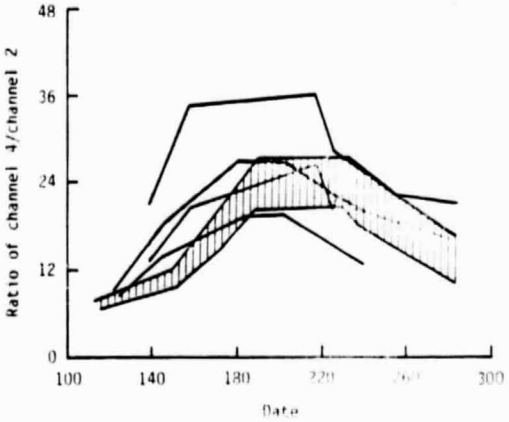

Figure 4.4-13. - Mean values of pasture for 1977-79.

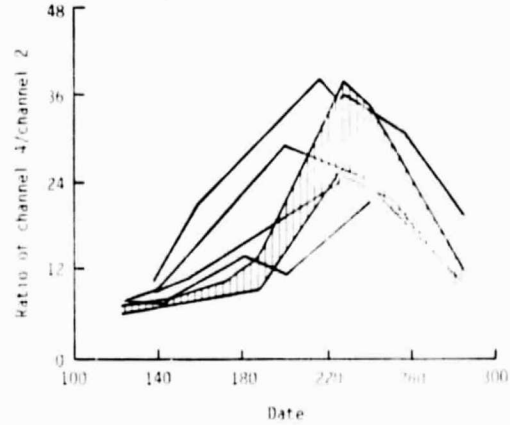

Figure 4.4-14. - Mean values of safflowers and sunflowers for 1977-79.

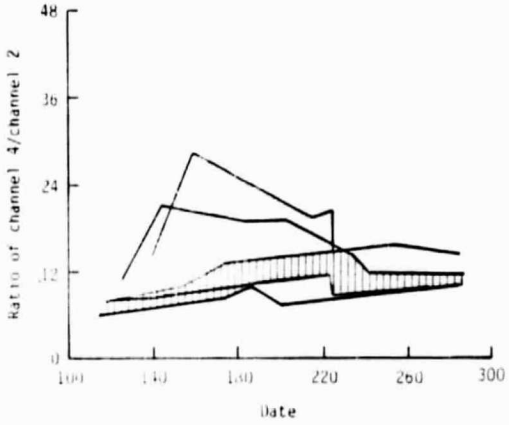

Figure 4.4-15. - Mean values of idle land for 1977-79.

5. SUMMARY AND RECOMMENDATIONS

This task was designed as an initial study of the usefulness of metsat data. In-house satellite data from Landsat 2 and 3 were used to simulate the spatial, spectral, and sampling methods of the NOAA-6 satellite data. The feasibility of some procedures was established by this study.

a. Geographical extension established that vegetation profiles will differ over separate areas, but they tend to be similar over the 5- by 6-nautical-mile area of a LACIE sample segment.

   Recommendation: The geographical limits of similarity should be established. The statement above is true for areas 4 by 4 kilometers (simulating GAC-scale simulation) in a 5- by 6-nautical-mile coverage.

   This should be tested over 25-kilometer-square areas that are dispersed similar to the geographical segments used in this study.

b. Cropping practices seem to determine the degradation of crop signature with LAC or GAC scales. In North Dakota, for example, strip-fallow spring wheat cropping led to degradation of signature at the LAC-scale simulation level; the LAC was unlike the signature of spring wheat and idle land, but it was stable between years and GAC-scale simulations. A heavily vegetated area, such as the corn and soybean belt, exhibited a summer crop at both the LAC-scale and the GAC-scale simulation. This signature was variable between years, perhaps because of vegetation vigor. An area with crops of different signatures (corn/alfalfa or pasture/soybeans) tended to exhibit identifiable signatures at the LAC scale, but the GAC-scale simulation, although stable over the segment, was unrepresentative of either. Another case was where the GAC-scale simulations, like the LAC-scale simulations, did not average the different signatures, but retained component characteristics at the GAC level, which were not similar over the 5- by 6-nautical-mile area.

   Recommendation: Crop information, specifically what crops were grown in a region, should be available for all use of metsat data. Usual field size, compared to the LAC scale of 1.1 kilometers and the GAC scale of 4 kilometers square, should also be available.

c. Episode events appeared to be evident in LAC- and GAC-scale simulations (sample segments 886 and 852).

Recommendation: Correlation of graphic anomalies with regional meteorological and agronomic data should be done for a number of vegetative indices including ratios.

d. LAC-scale simulation exhibits more variation than the GAC scale. This was of indeterminate usefulness. Perhaps LAC-scale coverages would be more useful than GAC in areas of disparate crops, such as corn and alfalfa.

Recommendation: LAC-scale and GAC-scale metsat data should be obtained for the same geographic area and information compared. Film products, image displays, and graphs should be correlated to agronomic and meteorological factors and the effectiveness of each evaluated.

e. Multiyear comparison of GAC-scale coverage indicated sensitivity to agronomic factors. This should be pursued, especially in a high vegetation area where a definite vegetation profile exists.

Recommendation: Agronomic factors such as yield should be correlated to the relative change in vegetation profile.

f. As one moves away from the center scans, more and more area is covered by each LAC- and GAC-scale pixel. These larger pixels could be useful in crop assessment studies.

Recommendation: Useful information should be correlated to spatial resolution.

g. It was assumed that AVHRR bands 1 and 2 would respond in a similar manner to Landsat channels 2 and 4.

Recommendation: Use the Exoteck-20 data form to further study information in the AVHRR bands.

h. Channel ratio proved to be an effective vegetation index with Landsat data and should be of comparable value with metsat data. The capability of graphing the individual channels (viewing the components of the ratio) was a valuable research tool.

Recommendation: Channel ratio should be used as a vegetative index with metsat data.

i. The GAC simulation is a little more consistent than could be expected from actual GAC data because of the sampling technique.

Recommendation: A statistical study on the impact of the GAC sampling technique on crop information should be done. This could be a continuation of the PATCH and SKIP subsampling processors (refs. 9 and 10).

j. The curve fit option was not as useful as expected as a data approximation in this study. Several of the segments had data patterns which could not be successfully represented by a curve.

Recommendation: Curve fit as an approximation should be tested when larger geographic areas are averaged and should be available as an option when Metsat data are used. Metsat data would have a larger number of acquisitions available and would probably have better acquisition distribution, so curve fitting may be more satisfactory than it was in this study.

k. Degradation of crop signature can occur at the LAC level, the GAC level, or not occur at all, depending on field size and cropping practices.

Recommendation: GAC coverage may be independent of field size and dependent only upon scene content. This should be investigated.

l. This project incorporated extensive use of the Landsat channel ratio as a vegetation index.

Recommendation: Material generated for this study should be reexamined and redocumented as a study on the use of channel ratio with Landsat data.

m. At the time this study was done, 1980 Landsat acquisitions were not available. For this reason, no correlation with actual metsat data was possible. Simulated and real metsat data should be compared.

Recommendation: A follow-on study comparing Landsat data with metsat data (1980 crop year) should be done. Also, expanding the multiyear study by adding 1980 data would be useful.

6. REFERENCES

1. Austin, W. W.: Recommended Data Sets, Corn Segments, and Spring Wheat Segments for Use in Program Development. JSC-17137, LEMSCO-15708, NASA/JSC (Houston), Apr. 1981.

2. Amery-Ryland, J. L.: Preliminary Study for Correlation of Metsat Data With Landsat Data. LEMSCO-17307 (to be published).

3. Badhwar, G. D.: A Program Called TRJPLT for Use on the PDP 11/45 Image Processor. Letter to J. D. Erickson, May 1979.

4. Kedwell, K. B.: NOAA Polar Orbiter Data User's Guide Preliminary Edition. National Climatic Center Satellite Services Division, Dec. 1979.

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6. Johnson, W. R.; and Sestak, M. L.: An Analysis of Haze Effects on Landsat Multispectral Scanner Data. JSC-17127, LEMSCO-15971, NASA/JSC (Houston), Apr. 1981.

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8. Vanderbilt, V. C.; Robinson, B. F.; Bichl, L. L.; Bauer, M. E.; and Vanderbilt, A. S.: Simulated Response of a Multispectral Scanner Over Wheat as a Function of Wavelength and View and Illumination Directions. Field Research on the Spectral Properties of Crops and Soils, vol. 1, SR-P0-04022, NAS9-15466, LARS-112680, Purdue Univ., November 1980.

9. Nieves, M. J.; O'Brien, S. O.; and Oney, J. K.: Computer Program Documentation for the PATCH Subsampling Processor. JSC-16855, LEMSCO-15119, NASA/JSC (Houston), Jan. 1981.

10. O'Brien, S. O.: SKIP Subsampling Processors User's Manual. JSC-16854, LEMSCO-15114, NASA/JSC (Houston), Nov. 1980.

11. Tappan, G. and Miller, G. E.: Area Estimation of Environmental Phenomena from NOAA-n Satellite Data. LEMSCO-17312, Nov. 1981.

APPENDIX A

METSIM: A PROGRAM DESIGNED TO SIMULATE METSAT DATA USING LANDSAT DATA

A.1 GENERAL INFORMATION

The software program METSIM was developed by Lockheed Engineering and Management Services Company, Inc., for use in the Early Warning Project of the AgRISTARS Program. METSIM is based on TRJPLT (ref. 3), a program written by Dr. G. D. Badhwar of the NASA/JSC, and it runs on a Digital Equipment Corporation (DEC) PDP 11/45 computer system that operates under a monitor console routine. METSIM is designed for the Tektronix graphics terminal and is implemented on the Interactive Multispectral Image Analysis System (Image 100) at the NASA/JSC, Building 17.

The meteorological satellites transmit two types of coverage: LAC data, and GAC data, (ref. 4). To simulate these data, pixels of Landsat data from a LACIE segment were grouped into 52 (lines) by 68 (columns) blocks. Each block was then grouped into a 4- by 4-, 16-cell grid; each cell contained 13 lines by 17 columns. A block, therefore, approximated the GAC, and a cell approximated an LAC pixel.

The simulated area mean values were processed by the METSIM routine, which produced graphs of cell mean values versus acquisition date and block mean values versus acquisition date. A curve was fitted through the mean values as an approximation of the data. The plots simulated the time trajectories to be expected when metsat data were used.

A.2 INPUT TO THE PROGRAM

The METSIM program is set up for interactive use. Input is on disk, and processing is done by user response to program query. Output is a graphic display on the Tektronix screen, which is automatically hardcopied. A statistical summary is output on the line printer.

The METSIM program operates from a 3046-block merged image file. This file has a minimum of four and a maximum of seven Landsat acquisition images plus the AA digitized ground truth pixel label (crop code and purity label). Files are designated SPLxxxx; for example, SPLØ886 is the merged image file for LACIE sample segment 886. Merged image files are located on disks, although program input could be from tape.

Each record is 38 bytes or less. The first six bytes are pixel coordinates (line and column numbers); these are three bytes each. Then, either 16, 20, 24, or 28 bytes, depending on the number of acquisitions, are arranged by acquisition. The pixel data are followed by a three-byte crop code and a one-byte pixel purity code.

A.3 PROGRAM OPERATION

METSIM requires interactive processing. The merged image file, either on disk or on tape, must be mounted prior to execution of the program. The Image 100 Tektronix graphics terminal with hardcopy facility and the Gould printer are required.

User answers are generally stated in the program queries; "Ø" (zero) indicates "no," and "1" indicates "yes." The run command is followed by use of the escape key; all query answers are followed by a carriage return (CR). Queries are in uppercase letters below; instructions for answering are in parentheses, and comments on the queries are in lowercase letters. Figure A-1 gives a block diagram of METSIM.

The user issues the command: RUN METSIM. The user then answers queries to the program as follows:

1. DO YOU WISH A SINGLE CELL (TYPE 1) OR 16 CELL BLOCK WITH MEANS AND STDS (TYPE Ø)?

   [type "1" or "Ø"]

   This query establishes a request for a single cell (LAC simulation) or a block (GAC simulation).

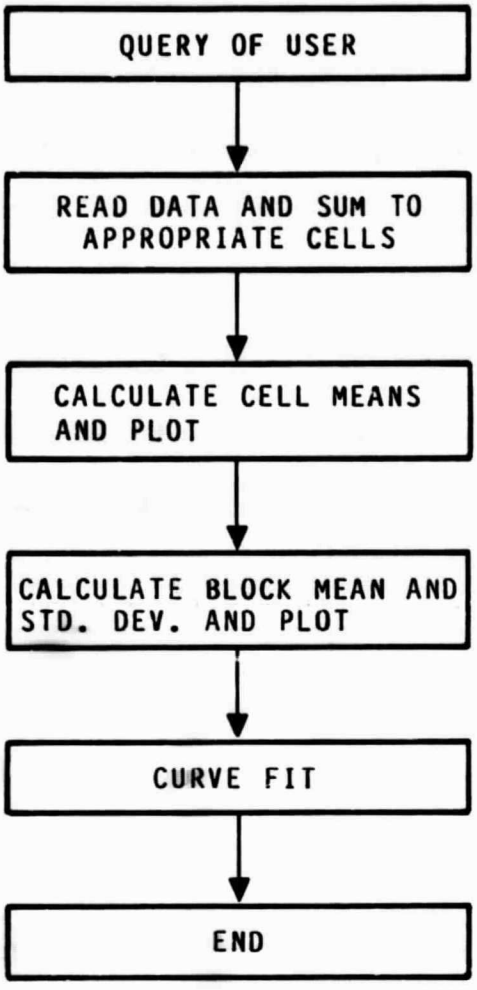

Figure A-1.- Block diagram of METSIM.

2. BEG LIN, BEG PIX.

[type in format XXX,XXX]

This query sets the position of the grid; it is asking for the upper left corner of the block location in lines and columns relative to the LACIE segment. If the answer to query 1 is "1," this query will appear:

2* INPUT CELL NO.

[type cell number (range "1" to "16")]

The cell number is relative to the grid position established in query 2. Coordinates of the cell relative to the segment (lines 1-117, columns 1-196) will be output on the graphs.

3. INPUT FILE DB2: [UIC] FILNAM.DAT.

[type "DBØ: [111,17] SPLØ886 DAT" for example]

Input the location of the merged image file: the device (DBØ or DB2), the user identification code [111,17], and the name of the file containing the data.

4. PURE (6) OR IMPURE (1-5) PIXELS?

[type "1," "2," "3," "4," "5," or "6"]

This refers to the AA pixel purity designations;[1] the program will accept only pixels of purity greater than or equal to the input value for use in calculating the mean values.

5. WHAT RANGE OF VALUES 2F1Ø 4 X COORDINATES?

[type "100.,300." for example]

This query sets the scale for the X-axis, the range of the acquisition dates.

---

[1]AA pixel identification is done on a subpixel level. Purity 6 pixels are those for which all six subpixels have the same identification; purity 1 requires one or more subpixels of the same label; hence, "1" defines an all-pixel input.

6. DO YOU WANT A CROP CODE?

[type "Ø" (no) or "1" (yes)]

This query allows the input for the mean values to be restricted to specific crop codes only. If the answer to query 6 is "1," this query will appear:

6* INPUT CROP CODE.

[type up to 4 AA codes in format XXX, XXX, XXX, XXX]

If, for example, 092 is entered here, only corn pixels will be used in the mean value computations. If the answer to query 6 is "Ø," this query will appear:

7. DO YOU WANT A FILTER? (Ø = NO, 1 = PRESET, 2 = USER INPUT]

[type "Ø," "1," or "2"]

If the query is answered "Ø," all crop codes will be accepted as input to cell mean values. If the answer is "1," a set of eight preset nonvegetative AA crop codes will be eliminated: 240, 241, 242, 250, 251, 252, 253, and 254 (water, mountains, nonagriculture, homestead, and idle cropland). If answer is "2," space is provided to enter up to eight crop codes which will be filtered out.

8. READ ACQUISITION DATES, IN RANGE OF XS.

[type Julian date of each acquisition as XXX., XXX., XXX., ...]

This inputs the acquisitions available from the SPL file; for example, 167., 204., 212., 231., 249., 258., 267., for SPLØ886 DAT.

9. HOW MANY ACQ ON FILE?

[type "4," "5," "6," or "7"]

This is the number of acquisitions merged to form the SPL file. This, as well as the acquisition dates required in query 8, must be known before beginning processing, because they are not available from the file.

10. DOES THIS HAVE LANDST 2 & 3 DATA?

[type "Ø" (no) or "1" (yes)]

"No" indicates all acquisitions are data from Landsat 2. If the answer to query 10 is "yes," this query will appear:

11. READ MASK OF LANDST 2 & 3 ACQ, 3(1).

[type series of "Ø," "1"]

Response to this query will be up to seven digits of Ø's and 1's, where 1 = Landsat-3 and Ø = Landsat-2, one symbol for acquisition.

12. GODDARD (Ø) OR OSCAR CALIBR (1).

[type "Ø," or "1"]

This applies a calibration factor to the Landsat-3 data to adjust the data range into that of Landsat-2. (See reference 5.)

13. DO YOU WANT TO FIT THE DATA?

[type "Ø," or "1"]

This query offers the option of approximating the data by a curve. If the answer is no, Ø, the user may wish to copy the screen before entering the CR as CR triggers an automatic screen clear.

14. READ INITIAL VALUES.

[type, for example, "2.4, 21.89, 2.32, 1.63"]

These four values are initial guesses for A, α, β, and t_0 in the curve used to fit the data $Pv^{(t)} = At^{\alpha} e^{-\beta t2}$, where $Pv^{(t)}$ is the reflectance at time t; t_0 is the estimated emergence date.

15. HOW MANY ACQUISITIONS FOR FIT?

[type number to be used in curve fitting]

Any acquisition not wanted in the curve fit can be eliminated by this and the next query. This is useful if one of the acquisitions on the merged files has poor quality data.

16. READ MASK FOR ACQ YES-1, NO-Ø, SEVEN VALS.

[type series of "Ø, 1"]

A.4 PROGRAM OUTPUT

All output is to paper. For single cells, a plot of the cell mean value in channel 4 divided by the mean value in channel 2 versus time is copied automatically from the Tektronix screen. This graph, figure A-2(a), gives segment numbers, the cell number, any crop code called for, the channels used for ratioing, the pixel coordinates of the cell referenced to the segment, and the mean values of the data.

Below is the statistical summary corresponding to figure A-2(a).

SEGMENT = 0886 CROP = 0 0 0 0 BEG LN = 14 BEG PX = 52

DAY = 167	NO = 8	CELL MEAN = 12	COUNT = 221
DAY = 204	NO = 8	CELL MEAN = 56	COUNT = 221
DAY = 212	NO = 8	CELL MEAN = 36	COUNT = 221
DAY = 231	NO = 8	CELL MEAN = 45	COUNT = 221
DAY = 249	NO = 8	CELL MEAN = 27	COUNT = 221
DAY = 258	NO = 8	CELL MEAN = 11	COUNT = 221
DAY = 267	NO = 8	CELL MEAN = 10	COUNT = 221

This output is for a single cell, cell 8, with block coordinates fixed at line 1, column 1. No crop code or purity level was specified. When the option of an approximating curve for the data is selected, a second graph is generated. Figure A-2(b) is an example of cell mean values fitted with a curve with six acquisitions used for the fit. Header information on this second graph includes the segment number; the pixel coordinates of the cell referenced to the segment; the converged values for A, α, β, t_0^3 (derived from the input initial values) and the errors in these values; the fitted values which are the values of the curve corresponding to the mean values of the data given on the previous graph; and the chi-square fit of the curve to the data. For figure A-2(b), acquisition 212 was omitted from the curve fit process. Hence, there were only six values given for the curve and acquisition data points.

For the block mean value, the mean values of the 16 component cells were overlaid on one graph. In addition to the information given on the cell plots, an overall mean value with standard deviation was given for each acquisition date. Figure A-3(a) illustrates the output for block position (001,001). For the second graph, figure A-3(b) header information is analogous to that for the single cell fig. A-2.

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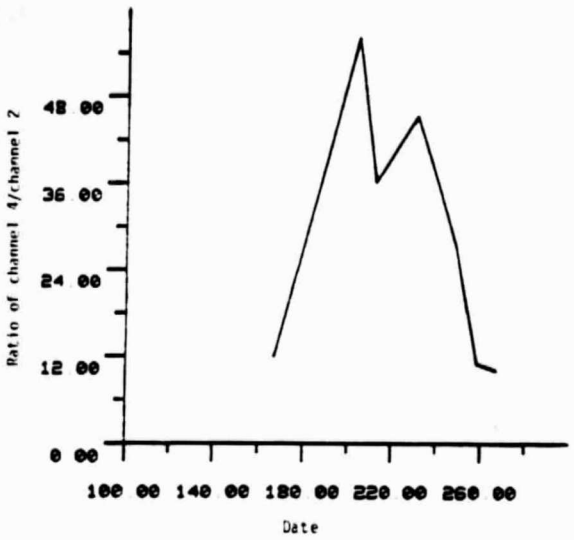

Figure A-2a. - Cell mean value versus time.

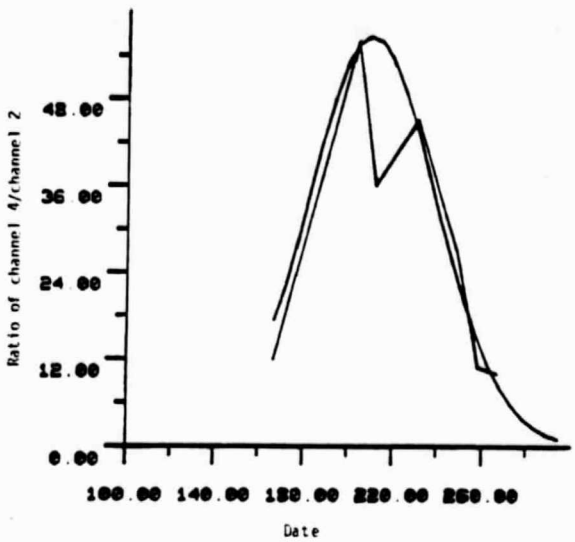

Figure A-2b. - Cell mean value versus time.

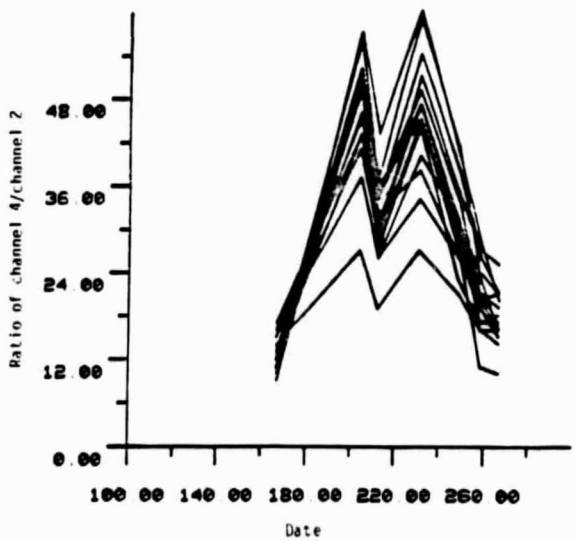

Figure A-3a. - Block mean values versus time.

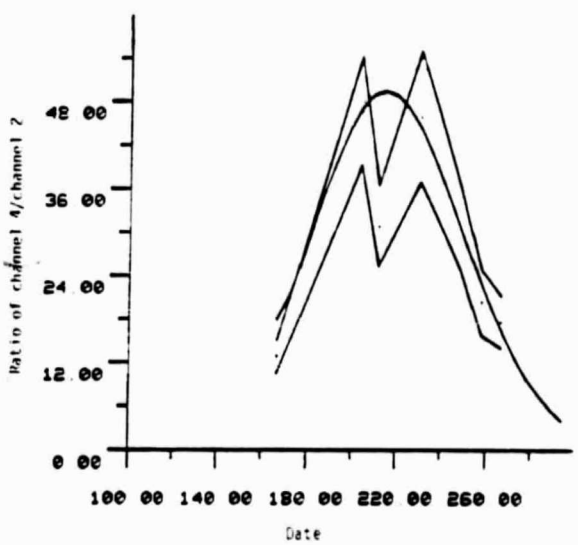

Figure A-3b. - Block mean value versus time.

Figure A-4 is a portion of the statistical summary. As with the single cell graphs, the segment number, the crop code indication, and the reference pixel coordinates of the block are given in the figure. All cells in the block are listed with acquisitions and corresponding mean values. In this summary, the number of pixels that were input to compute each of the cell means varied because only vegetation pixels were used. The preset filter in step 7 was applied.

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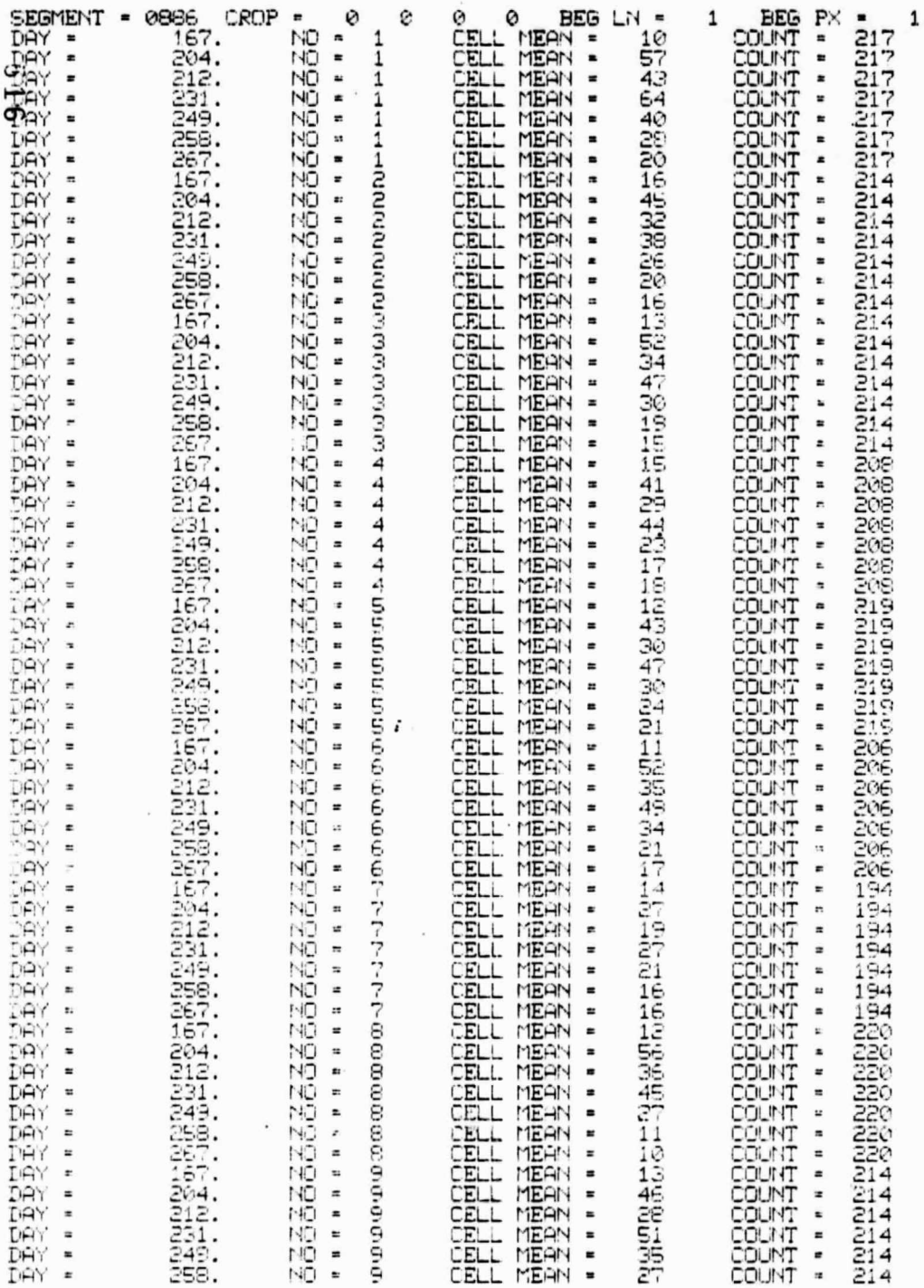

Figure A-4.- Statistical summary of sample segment 886.

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